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BULLETIN

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AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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OCTOBER 1928

THE MONTEREY SHALE OF CALIFORNIA AT ITS TYPE LOCALITY WITH A SUMMARY OF ITS FAUNA AND FLORA[1]

G. DALLAS HANNA[2]
San Francisco, California

ABSTRACT

The white organic shale exposed at Monterey was the first geologic formation of California to be described. It is largely composed of the siliceous skeletons of diatoms; radiolarians, silicoflagellates, foraminifers, fish remains, and mollusks occur in smaller quantity, the amounts being in the order named. Some difficulty has been experienced in identifying the formation elsewhere in the state on lithologic grounds and several synonymous or partially synonymous names have resulted. The bibliography indicates that most of the work on the paleontology of the formation has been done in Europe. The Monterey shale is of Miocene age and the top represents the last accumulation of pure, siliceous, organic strata in California. Unfortunately, however, there are vast quantities of such sediment in the state in a lower position in the geologic column than anything found in the Monterey section. Most of the oil in California is generally believed to have had its source in the organic constituents of the Monterey shale.

HISTORICAL NOTES

One of the best known parts of the geologic column in California is that group of Miocene strata commonly called "Monterey shale." It was one of the first formations of the state to be named and has the distinction of containing the first California fossil known to have been described. The formation is celebrated because of its vast thickness, its wide geographic distribution, and its exceptionally high content of

[1]Read before the Association at the San Francisco meeting, March 23, 1928. Manuscript received by the editor, July 11, 1928.

[2]Curator, department of paleontology, California Academy of Sciences, Golden Gate Park.

organic remains. It is generally supposed to be the source rock of almost all of the petroleum produced in California up to this time.

Credit for the discovery of the formation at Monterey and the enormous quantity of micro-organisms in it must be given to Alexander S. Taylor,[1] a resident of the town that was the first capital of California. This was not later than 1852, because European correspondents of his were soon after busily engaged in the study of the fossils in the samples. Thomas Brightwell described the first one in 1853; this was *Triceratium montereyii*, the locality being given as follows: "Fossil in a stratum of earth occurring near the shore of Monterey Bay, N. A., abounding in Diatomaceæ; furnished by Mr. A. S. Taylor of Monterey."[2]

Taylor also gave a piece of this earth to J. B. Trask of San Francisco, who mentioned it and its characteristics in a paper written in 1854.[3] Trask stated that the deposit contained five species of discoid diatoms, but he did not name them. He also stated that samples had been placed in the hands of J. W. Bailey and C. G. Ehrenberg for study. There is some evidence to indicate that Bailey published an account of the deposit in 1854, because the following title is carried in one of the bibliographies: "Fossil Diatomaceæ from California, U. S. Report, 1854." A considerable amount of search has thus far failed to reveal what report is meant or whether Monterey diatoms are mentioned.

W. P. Blake, geologist of the Pacific Railroad Survey, happened to be in San Francisco in June, 1854, and he received from Trask a sample of the Monterey shale collected by Taylor. Blake recognized the importance of the deposit and paid the locality a visit soon afterward. A preliminary notice giving the main geologic features of the type locality was published in 1855 or 1856.[4] Blake also gave a description before

[1]The repeated references to Dr. Taylor in the early history of California aroused the writer's interest in the man, and some effort was made to learn of his interest in science. Only one pertinent reference was found. H. Bancroft visited him about 1889 and described him as "a historical dabster of no small renown." He then lived at La Partera, 6 miles north of Santa Barbara, in squalid surroundings. (*History of the Pacific States*, Vol. 34, 1890, pp. 497-506). Taylor has the honor of having collected the only real California grizzly bear skull to be found in any museum until recently. The writer aided Harold Heath and William McGowan in a small way in securing the second specimen of this famous but now extinct mammal in 1927; the skeleton was found buried in the sand dunes 12 miles north of Monterey.

[2]*Quart. Jour. Micr. Sci.*, Vol. 1 (1853), p. 251, Pl. 4, Fig. 18.

[3]"Report on the Geology of the Coast Mountains, and a part of the Sierra Nevada [California]," *Senate Doc. No. 9*, Sess. 1854, pp. 1-88. (See pp. 21-23 for account of geology of Monterey.)

[4]"Notice of Remarkable Strata Containing the Remains of Infusoria and Polythalamia in the Tertiary Formation of Monterey, California," *Proc. Acad. Nat. Sci.*, Philadelphia, Vol. 7, communicated in April, 1855, pp. 328-31. (The title page of Vol. 7 bears the date "1856.")

the meeting of the American Association for the Advancement of Science at Providence in 1855, but nothing about it was published in the abstract of his paper.[1] His first account was somewhat amplified and corrected in 1856 and 1857.[2]

On November 12, 1855, Randall donated "Geological specimens illustrating the infusorial beds near Monterey" to the California Academy of Sciences.[3]

The geology at Monterey was scarcely treated for 35 years after Blake wrote, but paleontologists were busy and described many species from material collected by Blake, Taylor, or others.

The next geologist to describe the rock of the type Monterey was J. D. Whitney, in 1865, during the progress of the Geological Survey of California.[4] His account of the intrusive nature of the basement rocks, although in agreement in greater part with the view of Trask, was rather severely discounted by Lawson in 1893.

Becker,[5] somewhat later, made brief references to the subject in dealing with other diverse matters.

In 1893 Andrew C. Lawson[6] published a philosophic account of the geology of the area about Carmelo Bay, immediately south of Monterey, but the present writer considers this district to be outside of that which may properly be regarded as the type locality of the Monterey shale.

An excellent description of this type locality was published by Bruce Martin[7] in 1912, with a list of molluscan fossils.

The last published account of the locality to be mentioned is that by G. D. Louderback[8] in 1913. This is a general paper dealing with

[1] "Remarks upon the Geology of California, from Observations in Connection with the United States Surveys and Explorations for a Railroad Route to the Pacific," *Proc. Amer. Assoc. Adv. Sci.*, Ninth Meeting, Aug., 1855 (1856), pp. 222-25.

[2] "Observations on the Physical Geography of the Mountain Ranges of California, Adjoining the Coast," *Rept. Supt.* [*U. S.*] *Coast Survey for 1855* (1856), pp. 376-98. (See pp. 390-92.) *Pacific R. R. Repts.*, Vol. 5, Geological Report, 1857, pp. 180-82.

[3] *Proc. California Acad. Nat. Sci.*, Vol. 1, 1855, p. 79.

[4] *Geol. Survey of California, Geology*, Vol. 1, 1865, pp. 160-66.

[5] *U. S. Geol. Survey Bull. 19*, 1885.

[6] "The Geology of Carmelo Bay," *Bull. Dept. Geol. Univ. California*, Vol. 1 (1893), No. 1, pp. 1-59, Pls. 1-5, 1 map.

[7] "Fauna from the Type Locality of the Monterey Series in California," *Univ. California Pub., Bull. Dept. Geol.*, Vol. 7 (1912), No. 7, pp. 143-50.

[8] "*Univ. California Pub., Bull. Dept. Geol.*, Vol. 7 (1913), No. 10, pp. 177-241.

Miocene problems throughout California and is an invaluable aid to any subsequent studies. Very full references and abstracts of the greater part of the literature are given; the conclusions drawn from all the data then known are reasonable and just.

In the foregoing retrospect, brief and unimportant references have been purposely omitted. Likewise, papers dealing solely with paleontology have not been mentioned but will be referred to under that head on a later page.

THE TYPE LOCALITY

The type locality of the Monterey shale must be chosen to include the particular outcrop so well described by Blake.[1] This was situated on the slope facing the bay and two miles southeast of the center of the town. It was easily seen from the town and bay and was a conspicuous white spot surrounded by brush at an elevation of 200 to 300 feet above sea-level. It is now completely overgrown but is not difficult to find. It is on the northwest side of a long ridge which partially encircles the bay, and the exposure can be traced from the line of the Monterey-Salinas highway to and a little across the Monterey-Carmel highway. This is a distance of about 4 miles straight east and west and may properly be considered the type locality (Plate 7). Complications and uncertainties arise if an attempt be made to extend the area southward in Carmel Valley or eastward among a tangled mass of hills with many obscure folds. This definition of the type locality practically agrees with that given by Bruce Martin in 1912.[2]

The uppermost layers of shale are almost pure white, very light and porous, and are generally considered to form an especially good grade of diatomite. Little sand and clay are present (the principal impurity is a small quantity of acidic volcanic ash). This is the material discovered by Taylor and considered most fully by Blake in his description. It disintegrates readily under laboratory treatment and is the part of the deposit which has been most studied paleontologically. It is best developed on the north end of the ridge mentioned and ranges in thickness from 30 to 50 feet. The best and most accessible exposure is in the quarry of the Monterey Products Company 4 miles east of Del Monte on the Monterey-Salinas highway. The formation has been stripped for a considerable area and the particular part mentioned has been marketed rather extensively for the ordinary purposes for which diatomite is used.

[1] *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 7 (1855), pp. 328-31.

[2] *Univ. California Pub., Bull. Dept. Geol.*, Vol. 7 (1912), No. 7, pp. 143-50.

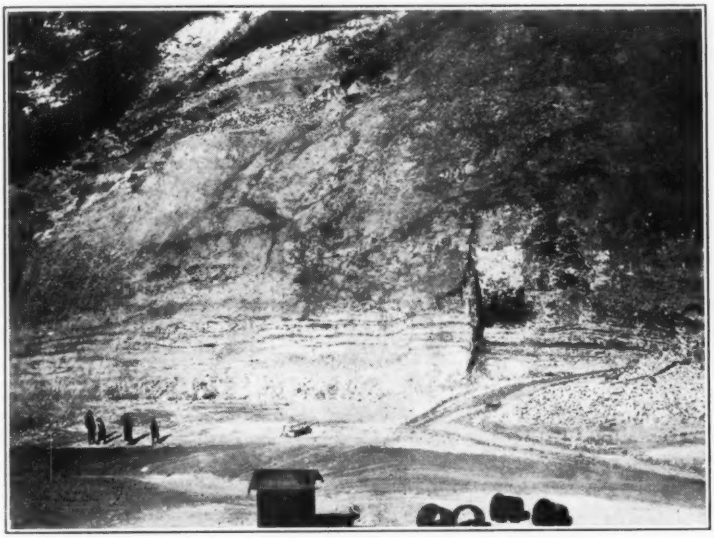

FIG. 1.—Exposure of Monterey shale 4 miles east of Del Monte, California, on south side of Monterey-Salinas highway; strata stripped of overburden by Monterey Products Company.

FIG. 2.—Part of U. S. Geological Survey topographical map of Monterey quadrangle, showing the type locality of Monterey shale. Scale: approximately 1:77,204.

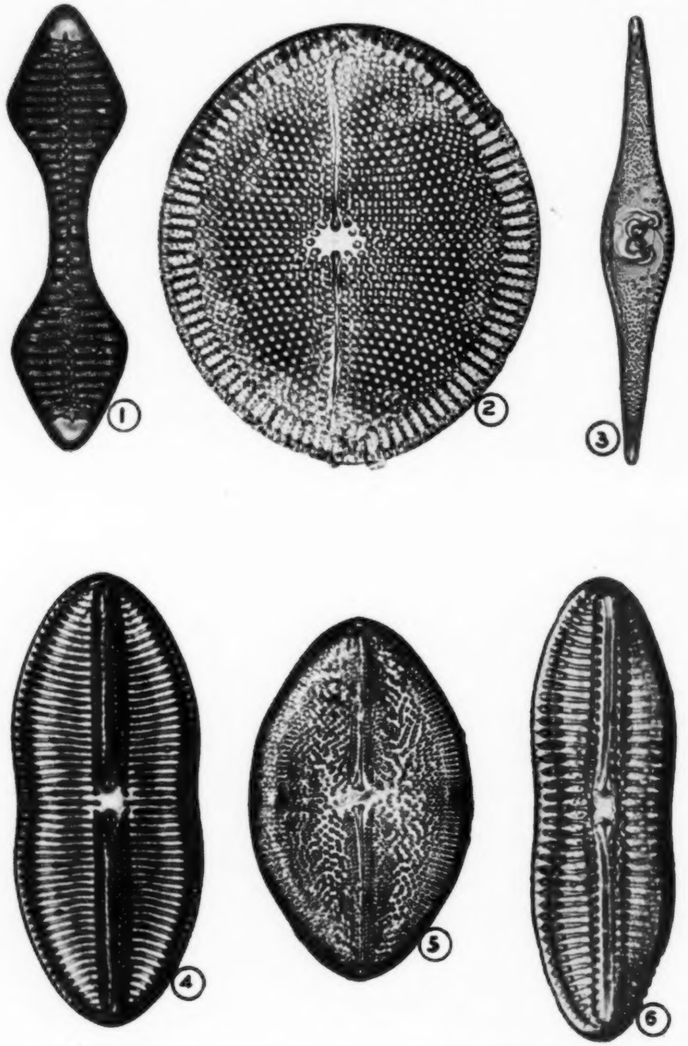

FIG. 1.—*Rhabdonema biquadratum* Brun. Plesiotype, No. 3,093 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; length, .1236 mm.; width, .0340 mm.

FIG. 2.—*Orthoneis splendida* (Gregory). Plesiotype, No. 3,094 (California Acad. Sci.) from Loc. 1,277 (California Acad .Sci.), Monterey section; Miocene; length, .090 mm.; width, .072 mm.

FIG. 3.—*Rutilaria epsilon* Greville. Plesiotype, No. 3,095 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; length, .1516 mm.; width, .0250 mm.

FIG. 4.—*Navicula ornata* Schmidt. Plesiotype, No. 3,092 (California Acad. Sci.) from Loc. 1,277 (California Acad. Sci.), Monterey section; Miocene; length, .2136 mm.; width, .0896 mm.

FIG. 5.—*Navicula abundans* Schmidt. Plesiotype, No. 3,096 (California Acad. Sci.) from Loc. 1,277 (California Acad. Sci.), Monterey section; Miocene; length, .1280 mm.; width, .0780 mm.

FIG. 6.—*Navicula ornata* Schmidt. Plesiotype, No. 3,097 (California Acad. Sci.) from Loc. 1,277 (California Acad. Sci.), Monterey section; Miocene; length, .1266 mm.; width, .040 mm.

Immediately below this uppermost "fluffy" part of the formation there is a greater admixture of inorganic impurities and the shale is generally of a light yellow or buff color. The total impurity, consisting largely of ash or altered ash, as a rule amounts to less than 50 per cent. Most of the siliceous organisms in this part of the formation are well preserved. Locally there are lenses or thin layers of wax-like opal in which the fossils are totally destroyed; this material is commonly called "chert." Calcareous fossils are normally leached out, leaving only the impressions, but in a few spots they have been beautifully preserved.

Succeeding this sort of shale, there is a gradual change downward in the section to harder material in which the amorphous silica of the fossils seems to have coalesced and formed a gray or yellowish rock, very soft and light in weight. This splits readily along the bedding planes and has been used locally for building purposes. It is very resistant to weathering influences; some buildings and fences erected 125 years ago are well preserved. Outcrops of this part of the formation are common near Monterey, the two upper parts just mentioned having been eroded away in most places.

All of the shales exposed at the type locality ridge are thinly bedded. A few blocks 6 or 8 inches thick can be found, but their average thickness is much less than this and many of them are "paper shales."

The basement rock is Santa Lucia granite, directly underlying the shales in some places. Elsewhere near by there are underlying sandstones and conglomerates of an indefinite age. Estimates of the total thickness of the type deposit range from 1,000 to 2,000 feet; the exact figure can hardly be obtained, but exposures a few miles toward the east are certainly as thick as the maximum figure. However, these thick exposures seem to contain much more Miocene than actually exists on the type locality ridge. Very embarrassing difficulties in nomenclature have arisen because of the extremely limited quantity of these shales at the type locality.

Sands and gravels of indefinite age overlie the Monterey shale unconformably in many places near the type section and call for no special comment.

The fossils of the type section have been extensively studied and if we include contemporaneous deposits elsewhere in the state it may be said that no formation in the west is better known, paleontologically. These fossils, taken with such evidence as stratigraphy affords, have enabled geologists to agree almost unanimously that the formation is Miocene. There has been some difference of opinion about the part of

the Miocene the formation occupies; it is generally supposed that it is about in the middle of the series, being overlain by the Santa Margarita or the San Pablo formation. This may be true, but the writer has not yet found the uppermost and best known diatomaceous stratum at Monterey, underlying Santa Margarita in any locality. Until such a situation is actually found the possibility must be recognized that the Santa Margarita and the San Pablo are sandy phases of a part or all of the type section of the Monterey. Neither the Santa Margarita nor the San Pablo are found at Monterey or at any other place the writer has seen where the uppermost Monterey shale beds are in place. The contact between the two sandy formations and the shales may or may not be marked by an unconformity, but the extreme top of the Monterey is certainly absent in many such places.

AREAL EXTENT AND SYNONYMOUS NAMES

The literature bearing on the geology of California contains a great many references to the existence of "Monterey shale" in various parts of the state. In most places such correlation was made on the basis of lithology, without consideration of more than a very minor part of the available fossils in the shales. Consequently such correlation must be attended with a measure of doubt. This difficulty has been unavoidable and will continue to be for a long time; it is brought about by the fact that not all Miocene siliceous shales are present at Monterey.

The entire Miocene epoch was essentially one of shale deposition in California, and such sediment as entered the various basins was largely acidic volcanic ash. Conditions were fairly uniform throughout the period and vast bodies of the shales have accumulated. One of the best exposures is in Kern County, along Chico-Martinez Creek, where the section is fully 8,000 feet thick.[1]

Much of the Miocene section of shales is indistinguishable, lithologically, from that exposed in the type Monterey, yet it was actually deposited very much earlier. A serious question of formational nomenclature therefore has arisen. Should all of the lithologically similar shales of the Miocene be called "Monterey," or only those which were deposited contemporaneously? Obviously the scientific way is to correlate as Monterey only those strata deposited when this formation was laid down, but there are good reasons for doubting the practicability of this method.

[1]E. G. Gaylord and G. D. Hanna, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9 (1925), No. 2, p. 229.

The top of the Monterey formation is so well known, paleontologically, that it is normally very easy to recognize wherever it may be found. Moreover, it is not known that there are any shales, similar lithologically, higher in the geologic column in California. However, the situation is far different with the base of the Monterey at the type section. This has not been adequately studied, paleontologically, and it is so modified, chemically, in most exposures that determinable siliceous fossils can not be extracted. For this reason and others it is commonly impossible to recognize definitely, with our present data, any part of the type Monterey in a shale exposure elsewhere.

That the Miocene shales of California can be subdivided into several well defined zones with plentiful and reliable paleontologic evidence is well known. The lowermost shales of this age studied by the writer[1] certainly differ paleontologically from those at the top at Monterey; this difference is sufficient to warrant segregation of a separate formation, but is hardly what would be expected if the two belonged to different epochs.

Again, the shales in the section near Bakersfield, generally referred to the Temblor formation, are different in their fossil content from those known at Monterey; they should properly be placed in a different formation. But it has been fairly definitely proved that the equivalent of the Temblor shales is not present in the lower part of the type Monterey.

The uncertainty regarding the exact lower limit of the type Monterey in the Miocene section has caused the establishment of a multiplicity of formational names for lithologically similar shales in other topographical provinces. Such names as Salinas shale, Maricopa shale, and Modelo shale are examples. It can be stated positively that the type sections of some of these formations contain strata exactly equivalent to at least a part of the type Monterey. Others may be lower *in toto* but may overlap some other named formation.

The situation is further complicated by the fact that the Miocene contains certain more or less local, arenaceous formations. These may have been deposited in shallow water near stream mouths or they may be the result of temporarily increased precipitation on surrounding land masses normally arid. In either case the sands furnished a habitat for marine organisms different from the ordinary organic oozes; consequently, they carry very different assemblages of fossils. Most of these inter-

[1] *Jour. Paleont.*, Vol. 1 (1927), No. 2, pp. 103-27, Pls. 17-21.

leaved sandy phases have received formational names based on paleontology or stratigraphy, although they may have been deposited contemporaneously with shale formations bearing other names.

How to unravel the tangled nomenclature of California Miocene is a difficult problem and one that requires much more study than has yet been given. In this paper the writer is dealing primarily with the type section of the Monterey, but it may be suggested that the most satisfactory procedure will be to determine the paleontology of the various shale members as thoroughly as possible and to evaluate the results from that work. The epoch was essentially one of shale deposition and contains plentiful micro-fossils throughout. Not all of these are extractable in any one section, but by a general survey in different sections and through a long period of study it is believed that the paleontology can be made known sufficiently well for proper subdivision into formations with recognizable definitions.

This will be a long and tedious process. The fossils concerned are so small that they tax the patience of the most persistent. Most of the fossils are diatoms, and if the very largest of these be taken as a basis of computation it is found that a cubic inch will contain about 100,000,000 individuals. Considerable equipment and some technique is required to handle and study such small objects; yet the task is not impossible. Enough experience has already been gained to warrant the statement that not only the top of the type Monterey can be recognized elsewhere by its diatoms, but several other strata in lower formations are equally distinctive.

Since the Monterey shale was the first of the Miocene formations to be described and is situated at the top of the organic series of shales, it is important that the paleontology of this be described as completely as possible. This will furnish a basis for correlation of strata of equivalent age elsewhere and the determination of formations of greater age. Considerable progress has been made already on such a study and it is hoped that it may be completed within a reasonable time.

GENERAL NOTES ON LITHOLOGY

The Miocene shales are generally so highly organic that they are considered to be the source of most of the petroleum in California. The chief contributors are naturally supposed to be the most plentiful organisms, the diatoms. Just how the hydrocarbons have been formed is not known as yet, but the matter is being subjected to intensive study by C. F. Tolman and his associates.

In some samples the hydrocarbons, if ever present, have migrated without leaving a trace, but this is exceptional. In most of the samples there is at least a residue left in recognizable amount, whether the samples be from anticlines, synclines, or monoclines.

The presence of such enormous accumulations of organic remains calls for some comment. Such deposits are being formed to-day only in deep and quiet lakes and the depths of the oceans, where they are called ooze. Neither of these conditions existed in the Miocene seas of California. In fact much of the diatomite accumulated in shallow water; the proof of this statement is found in the presence of ripple marks on some of the shales and the presence of fossil leaves; but the most important evidence is furnished by the diatoms themselves. A large number of those found in the purest organic shale of the type Monterey grew attached to shallow-water seaweeds. It is difficult to imagine such a deposit accumulating if much sand, clay, or mud was washed in by streams. The absence of such sediments except in minor quantity may imply that the adjoining land areas were eroded to base level, but the topography hardly bears this out in most places. A more plausible explanation lies in the assumption that the land masses near by were exceedingly arid throughout most of the Miocene. Such aridity could be caused by the existence of a mountain barrier on the west, and there is some evidence to support such a theory.

J. C. Branner[1] once suggested the theory that the enormous accumulation of diatoms during the California Miocene was due to their being brought from cold arctic waters. They were then concentrated in the bays and among the islands now forming the coast ranges. It is true that diatoms flourish in the arctic and antarctic regions to a greater extent than in temperate and tropical waters, but the Miocene diatoms themselves completely disprove such a migration theory. In the main, they are not pelagic forms.

Fine volcanic ash is a characteristic constituent of most California Miocene shales. The published analyses show this to be acidic in character, and it is quite probable that this material furnished the soluble silica out of which the siliceous skeletons of the organisms were built. The most puzzling problem in connection with this ash is to account for a source so uniform in quantity through so long a period of time. In the aggregate there must be hundreds of cubic miles of the material in the

[1] G. D. Louderback, *Univ. California Pub., Bull. Dept. Geol.*, Vol. 7 (1913), No. 10, p. 235.

Miocene. The writer cannot even venture to suggest the location of a source.

PALEONTOLOGY

Vertebrates.—The Miocene shales of California have furnished a considerable number of vertebrate animals, including sharks, rays, bony fishes, whales, sirenians, seals, and birds. The type Monterey, however, has furnished a single specimen and this is a small whale, *Balaenoptera ryani.*[1] Scales and bones of fishes are plentiful in the type section but these have not been identified.

Mollusca.—Fossils belonging to this group are noticeably scarce throughout the Miocene siliceous shales, and those at the type locality of the Monterey form no exception. The soft ooze of the ocean bottom probably would smother most forms of life. In his original account of the formation Blake[2] mentioned two species, *Tellina congesta* Conrad and *Lutraria traskei* Conrad. He also mentioned borings of *Petricola cylindracea*, but did not imply that the species lived during Monterey time as Martin inferred. Lawson[3] mentioned one species from the shale of Carmel Valley on the authority of W. H. Dall,—*Pecten peckhami* Gabb. He also listed a few genera, but mostly with doubt as to identity. The most complete account of the molluscan fossils is that of Martin[4] in 1912. The enviable reputation of this man as an expert collector leads to the belief that but few more of these fossils may be expected at that locality. Martin gave six species only:

Arca obispoana Conrad	*Venericardia montereyana* Arnold
Pecten peckhami Gabb	*Ficus kernianum* (Cooper)
Macoma congesta (Conrad)	*Marcia oregonensis* (Conrad)

In addition he mentioned several genera without specific names. The third was called *Tellina congesta* by Blake and Conrad; the sixth they called *Lutraria traskei.*

Foraminifera.—Fossils of this group are exceedingly plentiful in the Monterey shale at the type locality and elsewhere. This was pointed out

[1] G. D. Hanna and M. E. McLellan, *Proc. California Acad. Sci.*, Vol. 13, No. 14, pp. 237-41, Pls. 3-9.

[2] *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 7 (1855), p. 331.

[3] *Univ. California Pub., Bull. Dept. Geol.*, Vol. 1 (1893), No. 1.

[4] *Univ. California Pub., Bull. Dept. Geol.*, Vol. 7 (1912), No. 7, p. 148.

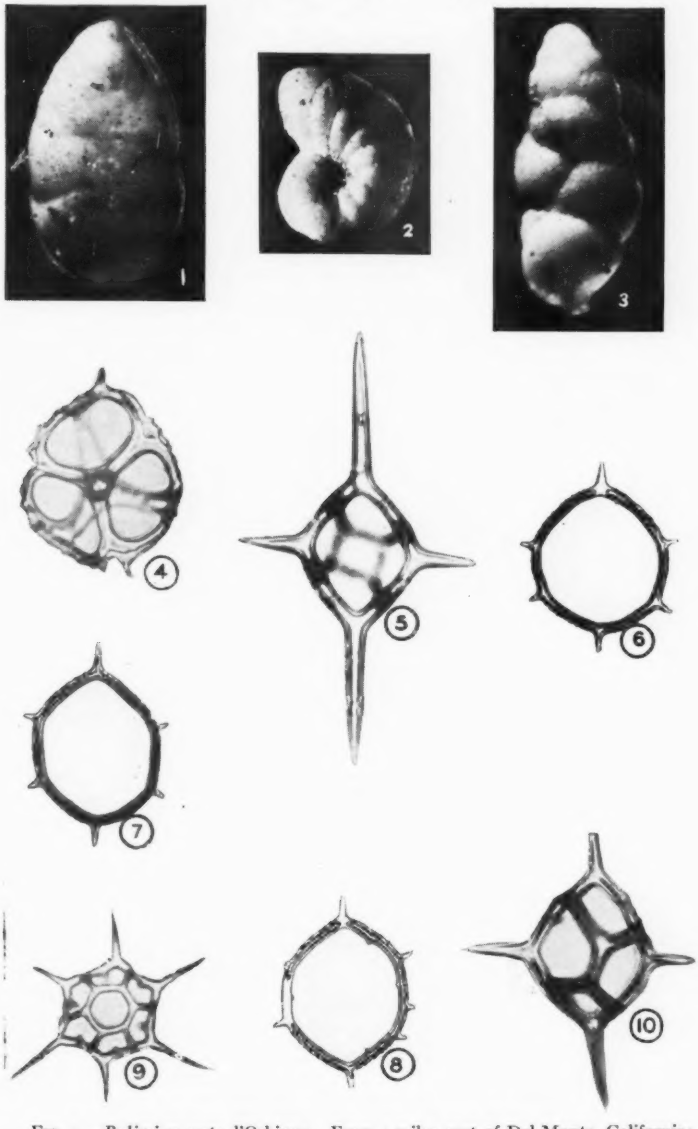

FIG. 1.—*Bulimina ovata* d'Orbigny. From 4 miles east of Del Monte, California; Monterey Miocene.

FIG. 2.—*Nonion incisa* Cushman. From 4 miles east of Del Monte, California; Monterey Miocene.

FIG. 3.—*Uvigerina californica* Cushman. From 4 miles east of Del Monte, California; Monterey Miocene.

FIG. 4.—Unidentified silicoflagellate. Plesiotype, No. 3,098 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; greatest diameter, .0464 mm., including spines.

FIG. 5.—*Distephanus regularis* Lemmermann. Plesiotype, No. 3,099 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; greatest length, .100 mm., including spines.

FIG. 6.—*Mesocena hexagona* Haeckel. Plesiotype, No. 3,100 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; greatest diameter, .0758 mm., including spines.

FIGS. 7, 8.—*Mesocena hexagona* Haeckel. Plesiotypes, Nos. 3,101, 3,102 (California Acad. Sci.) from same locality and same magnification as Figure 6. These three figures represent most of the variation noticed in some hundreds of specimens.

FIG. 9.—*Distephanus ornamentus* (Ehrenberg). Plesiotype, No. 3,103 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; greatest diameter, .050 mm., including spines.

FIG. 10.—*Dictyocha fibula* Ehrenberg. Plesiotype, No. 3,104 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; greatest length, .050 mm., including spines.

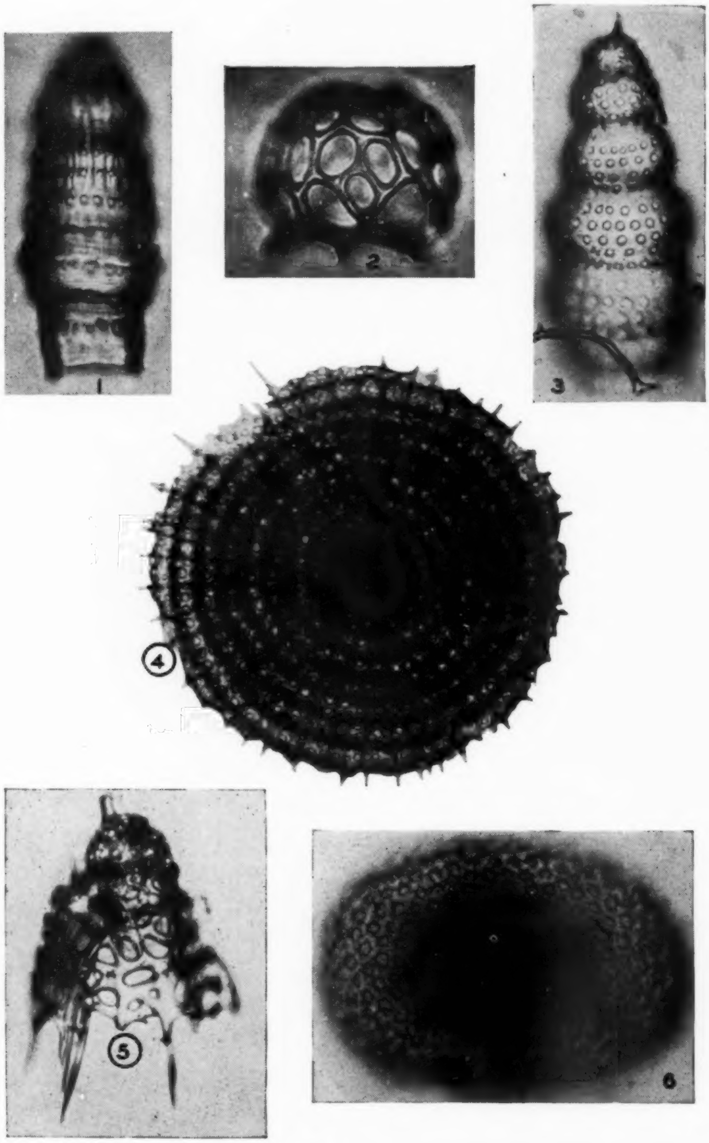

FIG. 1.—*Lithomitra lineata* (Ehrenberg). Plesiotype, No. 3,105 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; length, .1114 mm.; width, .0460 mm.

FIG. 2.—*Petalospyris* sp. Plesiotype, No. 3,109 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; diameter, .0388 mm.

FIG. 3.—*Eucyrtidium montiparum* Ehrenberg. Plesiotype, No. 3,106 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; length, .160 mm.; width, .0666 mm.

FIG. 4.—*Stylodicta accrescens* (Stöhr). Plesiotype, No. 3,107 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; diameter, .210 mm., not including spines.

FIG. 5.—Unidentified radiolarian. Plesiotype, No. 3,110 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; length, .1220 mm.; width, .0840 mm.

FIG. 6.—*Geodites* sp. An internal siliceous ball (sterraster) of a tetractinellid sponge. Plesiotype, No. 3,108 (California Acad. Sci.) from 4 miles east of Del Monte, California; Monterey Miocene; length, .1060 mm.; width, .0780 mm.

by Blake[1] in 1855 in his original description of the formation, but no topotypical species was actually studied until 1926, when J. A. Cushman took the matter in hand. He had two samples with which to work, one from "Road from Monterey to Pebble Beach, ¾ mile below Toll House on P. I. Co. road," and the other from "Two miles south of Monterey."

The title of his paper is: "*Foraminifera* of the typical Monterey in California,"[2] and in addition to the samples mentioned he included certain material from San Luis Obispo County, California, far to the southward. All of the species figured came from the latter locality; 50 are listed and unquestionably some of them do occur at the type locality of the Monterey but which they are can not be ascertained from the list and they are not included in the present summary. The first Monterey sample mentioned above is No. 333, Stanford University collections, Hannibal and Waring, collectors. The *Foraminifera* from a portion of this sample bear a strong resemblance to those from the San Luis Obispo County locality.

In most places in the formation calcareous fossils have been dissolved away, leaving, however, very accurate molds. This is one cause for the lightness and porosity of the building stone used locally for different purposes. There are some small areas so favorably situated that this leaching has not taken place, and here excellent collections can be made with ease. One of these places is in the quarry of the Monterey Products Company, 4 miles east of Del Monte; a few blocks of the material quarried out contain *Foraminifera* in great quantity in an excellent state of preservation.

Diatoms.—Since the Monterey shale is so largely composed of the siliceous skeletons of diatoms it might be expected that these fossils would be subjected to more extensive study than any of those already mentioned. A study of the literature proves this to be true. The records are found scattered through many papers, the most important of which are listed in the bibliography with this paper. The following list of 171 species and subspecies has been taken solely from published records. Undoubtedly some of the names are invalid, but the studies of the writer show that the shales contain many additional forms not here listed; the complete flora probably contains nearly 300 species. The formation

[1] *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 7 (1855), pp. 328-31.

[2] *Cont. Cushman Lab. Foram. Res.*, Vol. 2, (1926), Pt. 3, pp. 53-65, pls. 7-9.

contains a few species of silicoflagellates and several radiolarians, but the writer has not discovered that any named forms have been previously sted.

LIST OF DIATOMS REPORTED

Achnanthes subsessilis constricta Grunow
Actinocyclus confluens Grunow
Actinocyclus ehrenbergii Ralfs
Actinocyclus incertus Grunow
Actinocyclus ingens Rattray
Actinocyclus interpunctatus Ralfs
Actinocyclus laevigatus Grunow
Actinocyclus moniliformis Ralfs
Actinocyclus obscurus Rattray
Actinocyclus radians Rattray
Actinoptychus labratus montereyi Grunow
Actinoptychus grundlerii Schmidt
Actinoptychus interpunctatus Brightwell
Actinoptychus laevigatus Grunow
Actinoptychus minutus Greville
Actinoptychus nitidus Greville
Actinoptychus socius Schmidt
Actinoptychus splendens crucifera Grunow
Actinoptychus spinosus Ralfs
Actinoptychus undulatus Ehrenberg
Actinoptychus vulgaris Schumann
Amphitetras elegans Greville
Amphora angusta ventricosa Gregory
Amphora lanceolata (?) Cleve
Arachnoidiscus ehrenbergii evanescens Grunow
Arachnoidiscus ehrenbergii montereyana Grunow
Arachnoidiscus grevilleanus Hardmann
Arachnoidiscus indicus Ehrenberg
Arachnoidiscus ornatus Ehrenberg
Arachnoidiscus ornatus monteriana Schmidt
Asterolampra brebissoniana Greville
Asterolampra greveillei Wallach
Asterolampra marylandica Ehrenberg
Asterolampra retula Greville
Asteromphalus darwinii Ehrenberg
Asteromphalus variabilis Greville
Aulacodiscus browneii Norman
Aulacodiscus californicus Bailey
Aulacodiscus decorus Greville
Aulacodiscus kittoni Arnott
Aulacodiscus minutus Rattray
Aulacodiscus oreganus Bailey
Aulacodiscus probabilis Schmidt
Aulacodiscus pulcher Norman
Aulacodiscus simplex Rattray
Auliscus caelatus Bailey
Auliscus granulatus Bailey
Auliscus hardmanianus Greville
Auliscus mirabilis Greville
Auliscus punctatus Bailey
Auliscus quadriceps Bailey
Auliscus stockhardtii Janisch
Biddulphia aurita Brebisson
Biddulphia roperiana Greville
Campylodiscus coronilla Brun
Campylodiscus monterianus Grunow
Campyloneis grevillei W. Smith
Cerataulus johnsonianus Greville
Cocconeis ambigua montereyi De Toni
Cocconeis antiqua Schmidt
Cocconeis dirupta californica Cleve
Cocconeis distans Gregory
Cocconeis inflexa Schmidt
Coconneis interrupta Grunow
Coconeis notabilis Schmidt
Cocconeis prisca Cleve
Cocconeis probata Schmidt
Coscinodiscus antiquus Grunow
Coscinodiscus apiculatus Ehrenberg
Coscinodiscus apiculatus woodwardii Rattray
Coscinodiscus argus Ehrenberg
Coscinodiscus asteromphalus Ehrenberg
Coscinodiscus biradiatus Greville
Coscinodiscus cocconeiformis Schmidt
Coscinodiscus concavus Gregory
Coscinodiscus crassus Bailey
Coscinodiscus curvatulus Grunow
Coscinodiscus curvatulus recta Rattray
Coscinodiscus decrescens polaris Grunow
Coscinodiscus diorama Grunow
Coscinodiscus dubiosus Grunow
Coscinodiscus elegans Greville
Coscinodiscus exasperans Rattray
Coscinodiscus fimbriatus Ehrenberg
Coscinodiscus gemmifer Ehrenberg
Coscinodiscus gigas Ehrenberg
Coscinodiscus gigas laxa Rattray
Coscinodiscus gigas montereyi Grunow
Coscinodiscus griseus Greville
Coscinodiscus heteroporus Ehrenberg
Coscinodiscus interrupta Grunow
Coscinodiscus marginatus Ehrenberg
Coscinodiscus marginatus submarginata Grunow
Coscinodiscus nitidus Gregory
Coscinodiscus notabilis Schmidt
Coscinodiscus obliquus Rattray
Coscinodiscus oculus-iridis Ehrenberg
Coscinodiscus odontodiscus subsubtilis Rattray
Coscinodiscus omphalanthus Ehrenberg
Coscinodiscus pacificus Rattray
Coscinodiscus perikompsos Rattray
Coscinodiscus plicatulus Grunow

Coscinodiscus radiatus Ehrenberg
Coscinodiscus radiatus subaequalis Grunow
Coscinodiscus radiosus Grunow
Coscinodiscus spheroidalis Rattray
Coscinodiscus spinuliger Grunow
Coscinodiscus subconcavus major Schmidt
Coscinodiscus subtilis Ehrenberg
Coscinodiscus subvelatus Grunow
Coscinodiscus symmetricus Greville
Coscinodiscus tenuis Rattray
Coscinodiscus woodwardii Eulenstein
Cosmiodiscus elegans Greville
Cosmiodiscus tenuis Grunow
Craspedodiscus coscinodiscus Grunow
Craspedodiscus rhombicus Grunow
Cresswellia rudis Greville
Cyclotella radiata Brightwell
Denticula lauta Bailey
Ditylum undulatum Ehrenberg
Endyctia robusta (Greville)
Eupodiscus grevillei Ralfs
Eupodiscus oculatus Greville
Gephyria constricta Greville
Gephyria gigantea Greville
Glyphodiscus stellatus Greville
Hyalodiscus reticulatus Schmidt
Hyalodiscus subtilis Bailey
Lithodesmium minusculum Grunow
Mastogonia actinoptychus Ehrenberg
Melosira clavigera Grunow
Melosira separanda (Schmidt)
Melosira sol (Ehrenberg)
Melosira sulcata biseriata Grunow
Navicula angelorum Cleve
Navicula eudoxia Schmidt
Navicula lyra Ehrenberg
Navicula ornata Schmidt
Navicula oscitans Schmidt
Navicula praetexta abundans Schmidt
Navicula spectabilis Greville
Navicula subcincta Schmidt
Plagiogramma nankoorense Grunow
Podosira hormoides montereyi Grunow
Podosira maxima Kutzing
Pyxilla dubia Grunow
Rutilaria epsilon Greville
Rutilaria epsilon longicornis Tempere & Brun
Stephanogonia actinoptychus (Ehrenberg)
Stephanopyxis apiculata granulata Grunow
Stephanopyxis appendiculata paucispina Grunow
Stephanopyxis corona Ehrenberg
Stephanopyxis crassispina Grunow
Stephanopyxis marginatus californica Grunow
Stephanopyxis rudis Greville
Stephanopyxis turris Ehrenberg
Stephanopyxis turris longispina Grunow
Stictodiscus californincus Greville
Stictodiscus californicus ecostata Grunow
Stictodiscus hardmanianus Greville
Stictodiscus hardmanianus minor Schmidt
Stictodiscus kittonianus Greville
Triceratium alternans Bailey
Triceratium arcticum Brightwell
Triceratium arcticum californica Grunow
Triceratium inelegans Greville
Triceratium montereyii Brightwell
Triceratium parallelum Greville
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DISCUSSION

ANDREW C. LAWSON: Can diatoms be used for stratigraphic purposes?

G. DALLAS HANNA: The diatoms do not differ in this respect from other fossils. Some parts of the Monterey shale are characterized by special forms.

F. M. ANDERSON: I should like to ask Dr. Hanna what proportion of pelagic forms of diatoms are found in Monterey shales. It has been proposed heretofore that the accumulations of diatoms in this group of rocks are the

result of currents that have brought in the diatoms from the open sea. Is there actually a large proportion of pelagic forms in the general assemblage?

G. DALLAS HANNA: Only about 7 feet of the siliceous shales of the Miocene are known to be pelagic. The fossils of other known portions grew on the bottom or attached to algae or in other situations in shallow water.

NEPHELINE BASALT IN RICHLAND PARISH GAS FIELD, LOUISIANA[1]

IAN CAMPBELL[2] and A. D. MILLER[3]
Baton Rouge, Louisiana, and San Angelo, Texas

ABSTRACT

The writers describe briefly the geology of the new Richland Parish gas field of Louisiana, and the petrography of nepheline basalt discovered in the drilling. Gas was first encountered in this field in a well of the Gulf Refining Company in October, 1926. Development has proved a structure 14 miles long and 8 miles wide, with 150 feet of closure. Production comes presumably from the Glen Rose Trinity at depths ranging from 2,300 feet to 2,400 feet. An igneous rock was encountered in a well on the south flank of the structure, just below the Midway. It is a true nepheline basalt, of surficial type. Its age is probably late Cretaceous.

In January, 1928, at a depth of 2,477 feet, igneous rock was encountered in a well being drilled by the Moody and Seagraves interests in Richland Parish, Louisiana. While evidences of igneous activity in the form of tuff beds and volcanic ash deposits are not uncommon[4] in Louisiana, no igneous rock has been recognized within the state, to the knowledge of the writers, until this discovery. Because of this, as well as the fact that Richland field is one of the newer producing regions, a brief account of the geology of the area, and a description of the rock, may be of interest.

The well in which the basalt was found is known as Moody and Seagraves' Osborne No. 1. It is about 16 miles southeast of Monroe, in T. 15 N., R. 5 E., 660 feet south and east of the northwest corner of the NE. ¼ of Sec. 14 (Fig. 1).

The underlying geological conditions of this area are entirely obscured by recent material deposited by the Boeuf and Ouachita rivers, and occasionally the Mississippi, which overflow to a depth of approximately 15 feet. The country is flat or gently rolling. In the field the well elevations range from 65 to 85 feet above sea-level.

[1]Manuscript received by the editor, June 9, 1928. Published by permission of the Atlantic Oil Producing Company.

[2]Louisiana State University.

[3]Atlantic Oil Producing Company.

[4]M. A. Hanna, "An Interesting Volcanic Ash from Calcasieu Parish, Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10 (1926), p. 93.

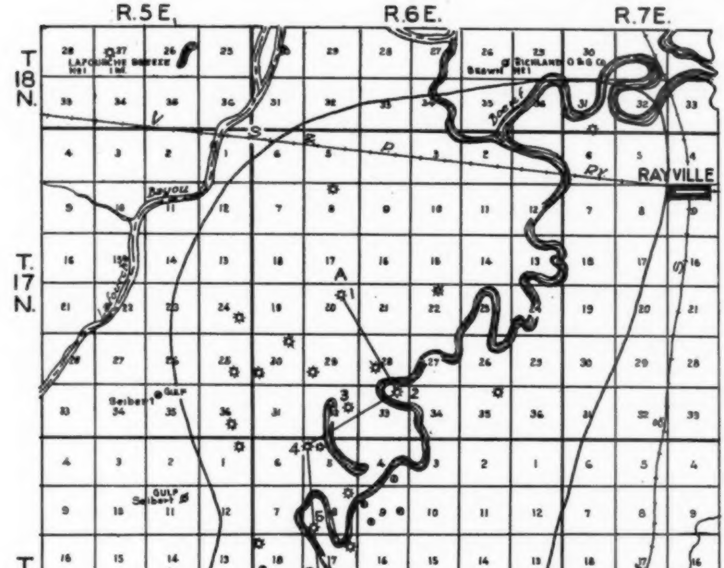

FIG. 1.—Richland Parish gas field, showing developments to date and probable limits of production (April 1, 1928). Each square = 1 square mile. (A. D. Miller.)

The Richland Parish gas field was discovered by the Gulf Refining Company when they drilled their England Planting Company No. 1 well in September, October, and November, 1926, in Sec. 32, T. 17 N., R. 6 E. While a core was being brought out of the hole from a total depth of 2,329 feet, the well blew out. Due to the high rock pressure and the large volume of gas, the drill stem was cemented in the hole and no attempt was made to set casing on the sand. This well was completed December 4, 1926, as an 8,000,000-cubic foot gasser. The total depth was 2,340 feet. Approximately 8 feet of pay sand was penetrated. Harry Oliver was also drilling his Hatch No. 1 well in Sec. 2, T. 15 N., R. 5 E., during the months of November and December, 1926. This well is 7½ miles south of the Gulf well. On December 31, this well blew out from a total depth of 2,316 feet as the driller was cutting a core, and flowed an estimated 75,000,000 cubic feet of gas. The core head penetrated 4 feet of the sand. Since that date many attempts were made to set 6-inch casing on the pay sand and complete this well as a commercial gasser, but the efforts failed and the well was finally junked and abandoned. A remnant of the Monroe gas rock was cored from 2,311 to 2,312 feet. It is believed that the gas is coming from the upper of the two producing horizons in the field. In this well the base of the Cane River was encountered approximately 175 feet higher than in other wells drilled in the area, with the result that much activity was manifested in acquiring protection land around the well.

The structure of the Richland Parish field proper, contoured on the top of the red shale, is shown to be approximately 14 miles long and 8 miles wide, with at least 150 feet of closure. The long axis of the structure strikes approximately N. 5° E. Two minor structures located on the northern and southern ends of the large structure have 75 feet and 50 feet of closure, respectively. The main structure is productive throughout its length and through approximately 4 miles of its breadth.

The Osborne well is on the southern flank of the major structure. This well is the result of a drilling campaign by the Moody and Seagraves interests. After the discovery of gas in Richland Parish late in 1926 by the Gulf Refining Company, the major companies operating in the general area commenced a very active leasing and drilling campaign. In June, 1927, the Moody and Seagraves interests leased a large area and immediately began drilling. It was questionable, when this well was begun, whether production would be obtained so far south. The Eocene beds, particularly the basal Cane River, were higher than those found in the field and were normal in thickness. The presence of the igneous

material at 2,475 feet makes it impossible to say just how the formations in this well would have been correlated with the red shale, beyond the probability that the position of the Midway was approximately normal as compared with its position in the producing wells of the field, when the igneous material was encountered. The location of this well is marked on the map by a double circle.

As a result of the comparison of the plotted log of the Osborne well with logs of other wells in this area on which considerable evidence was obtained from cores, the depths of the following formation contacts were approximated (Table I and Fig. 2): base of Recent, 10 feet; base of Quaternary, 70 feet; base of St. Maurice (Eocene), 200 feet; base of Sparta sand (Eocene), 785 feet; base of Cane River (Eocene), 1,020 feet; base of Wilcox sand (Eocene), 1,800 feet; base of the Midway (Eocene), 2,473 feet; base of weathered igneous material (?) 2,477 feet; igneous material to 2,501 feet. The weathered material is questionable, due to the fact that there is some doubt on the part of the Moody and Seagraves interests as to whether or not the bit went from the Midway shales directly into the igneous material (see Fig. 3 for correlations).

Several small chips of this igneous material were obtained and made available for study, and two of these were large enough to make thin-sectioning practicable.

The larger and the fresher of these two was from a depth of 2,497 feet. Megascopically this rock appeared dark and aphanitic; under a hand lens, small grains of olivine could be recognized. The specific gravity was 3.03.

In this section, the following minerals were identified (see Plate 11, Fig. 1).

Augite.—This is the most plentiful mineral in the section. It occurs in euhedral crystals, ranging from very small to 1 mm. in length. The average length is about 0.30 mm. The crystals are elongate parallel with the prism, and flattened parallel with the orthopinacoid. Twinning is common parallel with 100. Hour-glass structure occurs in a few of the larger crystals. The mineral shows distinct pleochroism, reddish-violet to blue—undoubtedly a titaniferous pyroxene. It is quite fresh.

Olivine.—Although not the most plentiful, this is still the most striking mineral in the section, because it occurs in large and remarkably fresh euhedral crystals. The length of some is as much as 1.50 mm. parallel with *b*. The average length is about 0.50 mm. The mineral is clear and colorless, and in sections normal to an optic axis shows a practically straight bar, indicating a composition of approximately 13 per

TABLE I

LOG OF MOODY AND SEAGRAVES OSBORNE NO. 1

Location, Richland Parish, Louisiana, Sec. 14, T. 15 N., R. 5 E. Elevation, 65 ± feet. Commenced, Nov. 12, 1927. Completed, Feb. 14, 1928. Initial production, dry and abandoned. Total depth, 2,501 feet.

Feet	
10	Clay
40	Sand and gravel
70	Sand
90	Sticky clay
91	Rock
162	Sandy gumbo and boulders
200	Sandy gumbo
281	Water sand
284	Rock
305	Sandy gumbo
420	Sand
421	Rock
479	Sand and boulders
480	Rock
620	Sandy shale and boulders
645	Sandy shale
668	Sand and boulders
690	Sandy shale
697	Sand rock
783	Sticky shale
784	Rock
880	Sandy shale
928	Sticky shale
975	Sand and boulders
985	Sticky shale—10-inch casing
1020	Sticky shale
1055	Water sand—flowing salt water
1060	Gumbo
1070	Sand and boulders
1078	Sand rock—strong salt water flow
1085	Sandy shale
1095	Gumbo
1145	Shale and boulders
1205	Sticky shale
1280	Shale
1295	Gumbo
1400	Sand
1440	Shale
1470	Sand
1540	Shale, lignite, and boulders
1565	Sand
1604	Sticky shale
1641	Rock
1710	Sand and boulders
1745	Gumbo
1750	Sand rock
1770	Gumbo
1774	Sandstone
1780	Gumbo
1800	Broken lime and shells
1830	Black sticky shale
1845	Broken lime
1900	Black shale
1920	Broken lime
1935	Black shale
1940	Sticky shale
1970	Broken lime
1975	Gumbo
1978	Lime
2050	Gumbo
2054	Lime
2060	Gumbo
2070	Lime rock
2073	Gumbo
2155	Broken lime
2290	Broken lime
2292	Gumbo—6-inch casing
2302	Broken lime
2324	Black shale and lime
2359	Black shale and boulders
2373	Sticky shale
2405	Black shale and boulders
2425	Sticky shale and boulders
2437	Black shale and chalk
2439	Cored—upper part of core was mashed sticky shale and fragments of concretions; lower part, shale and sandstone
2443	Streaks of sand and pyrite
2456	Black sandy shale—cored
2466	Sandy shale
2475	Sticky shale and boulders, sand, and streaks of pyrite
2501	Igneous rock

cent *FeO.*[1] It is without inclusions except for a few scattered grains of magnetite. Fracture cracks are common, but not plentiful. Along a

[1] A. N. Winchell, *Elements of Optical Mineralogy*, Vol. II, John Wiley and Sons (1927), p. 166.

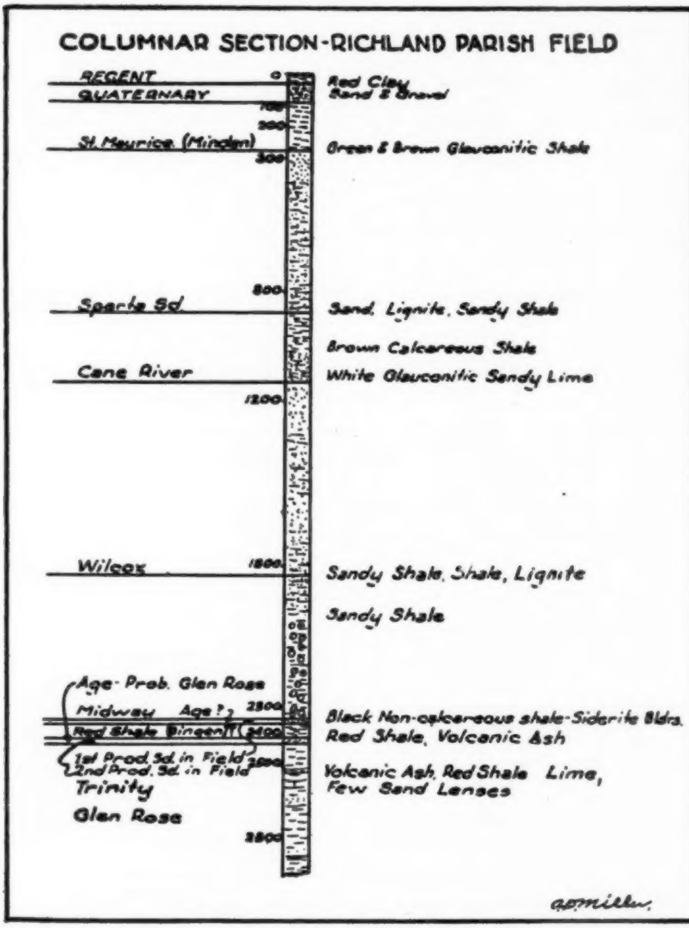

FIG. 2.—Columnar section, Richland Parish field. Depths shown in feet.

few of these cracks, incipient alteration to serpentine has taken place, but most of the crystals are entirely unaltered.

Nephelite.—This mineral makes up the larger part of the groundmass of the section. It is anhedral. Much of it is clear and limpid, but part has altered to a fibrous zeolite, presumably natrolite. Other zeolites may

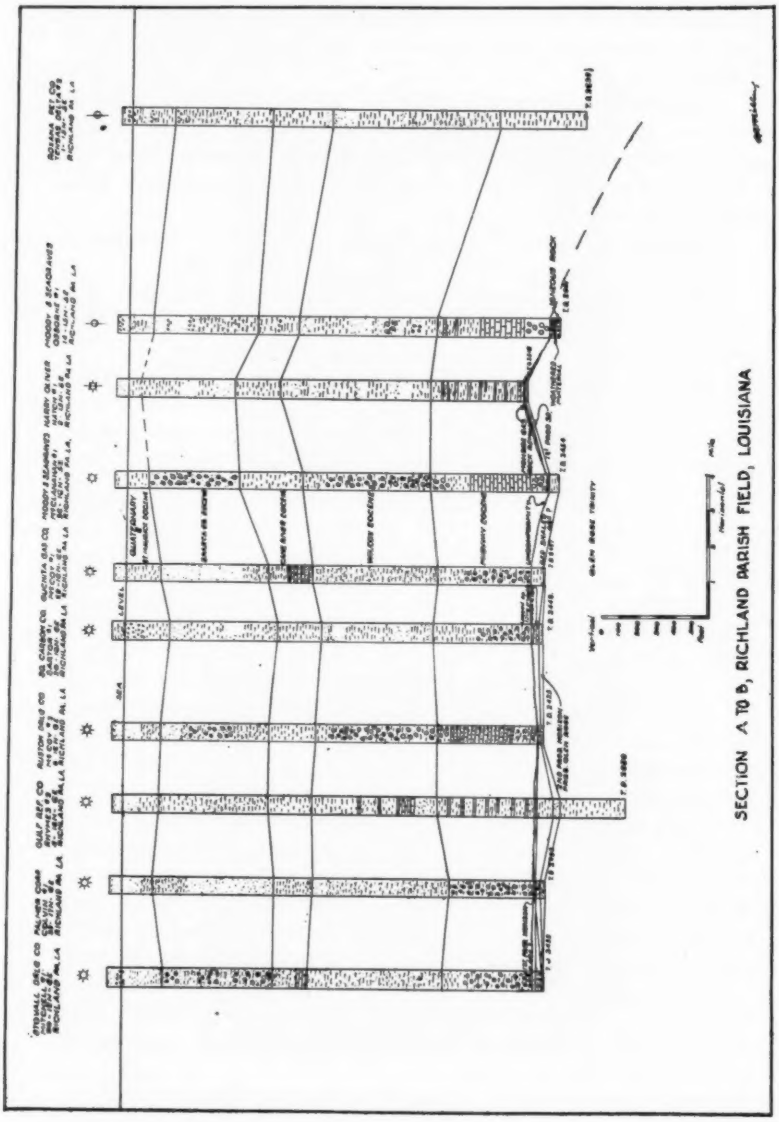

FIG. 3.—Section *AB*, Richland Parish field, Louisiana.

be present in small amount, but their species is indeterminable. They, and the natrolite, are clearly secondary, produced by alteration of the nephelite.

Apatite.—Apatite occurs in long slender prisms, some as much as 0.75 mm. in length. The fact that these exceedingly slender crystals are fractured very little and offset not at all would seem to indicate that the rock has not been subjected to any considerable movement or stress since consolidation.

Magnetite.—Magnetite occurs rather plentifully in disseminated euhedral to subhedral grains, averaging 0.3 mm. in diameter.

Biotite.—Only a few small subhedral flakes of this mineral occur in the section. It is deep brown in color and strongly pleochroic. Here and there a flake shows a very slight alteration to chlorite.

Glass.—A few small areas of brownish glass were noticed. These show no recognizable structure.

The order of crystallization of the primary minerals and their approximate percentage in the section, are as follows:

	Per Cent		*Per Cent*
1. Magnetite	13	4. Apatite	1
2. Olivine	12	5. Biotite	1
3. Augite	46	6. Nephelite	25
		7. Glass	2

This mineral composition corresponds with that of a typical nepheline basalt,[1] and the rock has been so classified.

The second specimen was from a depth of 2,486 feet (see Plate 11, Fig. 2). To the unaided eye this appeared much like the first, except that it was obviously more altered, having a somewhat greenish hue, and was streaked with areas of whitish alteration products. Further, it was amygdaloidal.

Under the microscope it was evident that this specimen was from the same mass as the preceding. The only differences were in the degree of alteration and the amygdaloidal character. In this specimen the olivine has been almost completely changed to serpentine; the nephelite is largely altered to zeolites, and the biotite is partly altered to chlorite. Augite, magnetite, and apatite are quite fresh, as in the first specimen.

The amygdules are fairly plentiful, but are all small, none being more than 2 mm. in diameter. They are only partly filled, chiefly with natrolite. They are circular in cross section, quite symmetrical, and give no evidence of flowage.

[1] G. W. Tyrrell, *The Principles of Petrology*, E. P. Dutton and Co. (1927), p. 129.

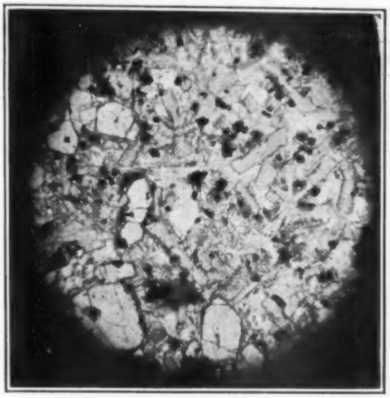

FIG. 1.—Thin section of nepheline basalt from a depth of 2,497 feet. Magnification × 20. The colorless mineral with high relief is olivine; augite appears slightly shaded; magnetite is black; the groundmass is nephelite. Notice the long, slender crystal of apatite near the center of the section.

FIG. 2.—Thin section of nepheline basalt from a depth of 2,486 feet. Magnification approximately × 20. Notice the more altered character of this specimen in comparison with Figure 1, above.

It is evident that this is an extrusive rock. The fine-grained texture, coupled with the amygdaloidal character and the presence of glass, clearly indicate its volcanic relationships. Further than this, it is difficult to come to any precise conclusions about the occurrence. Because of the much more altered condition of the minerals in the upper specimen, and the possibility previously mentioned, that a few feet of weathered igneous material overlies the bed rock, it seems unlikely that the rock could be a sill. Most probably it represents a small flow or perhaps a volcanic neck.

Rocks of somewhat similar type have been recognized elsewhere in this general province. Osann[1] described a nepheline basalt from Uvalde County, Texas.[2] He quotes Dumble as saying that these rocks are in the upper part of the Lower Cretaceous. According to Vaughan[3] all the occurrences in this area are intrusive. The youngest rocks cut by the intrusions are of uppermost Cretaceous age. Kemp[4] has described a rock rather similar to this Louisiana occurrence from Pilot Knob, Texas. This occurred as a small, somewhat isolated marine volcano. Its age was definitely determined as being in the latter part of the Austin epoch.

All that we can say of the age of this Richland Parish rock is that it is definitely pre-Midway, probably post-Glen Rose and perhaps post-Marlbrook. Presumably it represents a small and isolated phase of the igneous activity common along the southern flanks of the Ouachita Mountains in late Cretaceous time.

In conclusion, the authors wish to acknowledge their indebtedness and to express their thanks to the officials of the Atlantic Oil Producing Company, who were kind enough to make available to them all information on file regarding the Richland Parish field and the area south of it. Their thanks go also to Brokaw, Dixon, Garner, and McKee, geologists and engineers for the Moody and Seagraves interests, who furnished the samples of the igneous rock and the log of the well, and to The Texas Company and the Gulf Refining Company, for their coöperation. E. H. Finch, Division Geologist for the Atlantic Oil Producing Company of Shreveport, has given many helpful suggestions and criticisms during the preparation of the article. E. S. Larsen of Harvard University has kindly checked the petrographic determinations.

[1] A. Osann, "Melilite-Nepheline-Basalt and Nepheline Basanite from South Texas," *Jour. Geol.*, Vol. 1 (1893), pp. 341-46.

[2] T. W. Vaughan, *U. S. Geol. Survey Folio 64*, Uvalde, Texas (1900). Petrography by Whitman Cross.

[3] T. W. Vaughan, *ibid.*

[4] J. F. Kemp, "Notes on a Nepheline Basalt from Pilot Knob, Texas," *American Geologist*, Vol. 6 (1890), pp. 292-94.

POSSIBLE DISTILLATION OF OIL FROM ORGANIC SEDIMENTS BY HEAT AND OTHER PROCESSES OF IGNEOUS INTRUSIONS; ASPHALT IN THE ANACACHO FORMATION OF TEXAS[1]

CHARLES LAURENCE BAKER[2]
Houston, Texas

ABSTRACT

Rock asphalt is present in great amount in the Anacacho limestone and is associated with many igneous intrusive rocks. The intrusions are either later than or contemporaneous with the oil source strata and the asphalt-bearing rock. It is suggested that the oil was originally in bituminous shales older than the intrusive rocks and was distilled and caused to migrate to higher levels as a consequence of intrusive processes and effects. At least, it is certain that large amounts of asphalt and tar now occur in close juxtaposition to the igneous masses, which certainly left intact a large quantity of the oil originally present in the intruded strata.

Some of the known occurrences of hydrocarbon, methane, and other combustible gases in craters during the hottest and most active phases of vulcanism are cited. Probable lack of a sufficient supply of oxygen may be the reason these gases are not consumed in the intense heat of active vulcanism. Hydrocarbon gas and methane may be derived from bituminous and carbonaceous sediments intruded by molten rocks, perhaps from carbonaceous rocks, by combination with highly heated and dissociated water vapor. Carbon dioxide and carbon monoxide may have their source in intruded limestones and other calcareous rocks. Oil and gas under these conditions perhaps are characterized by some percentage of sulphur or sulphur compounds.

A discussion of the dates of Balcones faulting is included.

The view set forth in the writer's account of the Panuco oil field, Mexico,[3] that occurrences of oil at Panuco and elsewhere go far to disprove the validity of the carbon-ratio hypothesis, is likely to be opposed, perhaps by most petroleum geologists. It is therefore pertinent and useful to direct attention to other localities where oil occurrence possibly is inconsistent with the universal application of this hypothesis. At the same time it appears pertinent to discuss somewhat cursorily the possible rôle of igneous intrusion in distilling hydrocarbons from organic sediments. Four such possible occurrences are known within the United States, and others in Mexico and Brazil. One is the large amount of

[1]Manuscript received by the editor, July 9, 1928.

[2]Chief geologist, Rio Bravo Oil Company, 529 Commercial Bank Building.

[3]Charles Laurence Baker, "Panuco Oil Field, Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 4 (April, 1928), pp. 395-443.

asphalt and tar in the Anacacho and other porous Cretaceous formations of the Balcones fault zone, which extend a distance of 100 miles from the east line of Medina County to the western end of the Anacacho Mountains in Kinney County, Texas.

It is also well to notice the possibility that distillation of oil by igneous action is a different matter from total destruction of oil by such action. Part of it may have been distilled and part may have failed to be destroyed. The supply in the original horizon may have really increased through migration of oil distilled from other horizons, although some of that in the original horizon may have been destroyed by intrusive action. Oil may have migrated into its present horizon either previous to the intrusion or subsequent to it. It is certain that no very large quantities of oil in the two principal fields of Mexico were destroyed by igneous activity, which is really equivalent to saying that the destructive action of intrusives is confined, at most, to a relatively small zone near the intrusives. That is the important point. Hence the actual Mexican conditions demonstrate reasonably well the folly of condemning an area in which many intrusions occur, solely because of their presence. In Mexico, therefore, the fact is sufficiently clear. The same is true in connection with the Texas region about to be described. Intrusive masses are plentiful. They are at least in part definitely known to be younger than the petroliferous sediments, yet large supplies of bitumen exist in the closest possible juxtaposition to the intrusive bodies. We can not be sure that the existing bitumen has actually been distilled by the intrusives, but we are certain that very little of the oil was destroyed by intrusive activities. What we do know is amply sufficient for our present purpose, namely, to show that the carbon-ratio hypothesis fails, at least in some places, to explain known facts.

There is no essential difference in kind between dynamo-regional metamorphism and igneous contact metamorphism, at least in connection with the matter under discussion. There is a difference in degree. No one would reasonably expect to find much oil, or coal either, in intensely metamorphosed Basement Complex crystallines. But there are degrees in metamorphism and especially marked local differences in degree. To some conditions the carbon-ratio hypothesis probably applies and to such applications we can not object. The difficulty with that hypothesis seems to be that its application has been too general. It is a matter in which one fact outweighs all unproved theories. When dealing with partly metamorphosed rock, two other conditions must also be considered. These are (1) whether all the oil was actually consumed, and

(2) whether all the oil escaped through dynamo-regional effects. Here again we can be definite. The active seepages in the Mexican Cordillera occur in rocks fully as highly deformed, fully as much metamorphosed as any of the Paleozoic rocks in the Appalachians south of northern Pennsylvania. At and near Marathon, Texas, water wells in rocks equally highly deformed have yielded oil for years.

It is but a further step in the inquiry to a consideration whether in some places igneous action, if not, indeed, dynamo-regional metamorphism, may not have aided in the formation of utilizable oil as well as in its storage. The Benton (Eagle Ford) of Texas is everywhere markedly bituminous, but the shale of that stage is remarkably retentive of its oil content. Any process which would drive the oil from the shale and allow it to accumulate in more productive strata deserves thorough investigation. Hence the reason for the following discussion.

This is one of the questions demanding open-mindedness on the part of the investigator. It seems that igneous distillation of profitable amounts of oil can not yet be conclusively proved or disproved. All that the writer intends to show is such a possibility.

THE BALCONES FAULT ZONE OCCURRENCES

Dates of Balcones faulting.—It is not possible to determine directly the epochs of Balcones faulting, since only Cretaceous surface rocks are now seen to be faulted. There is considerable probability that there were lines of weakness originally developed in the Basement Complex rocks. The widespread igneous activity, both intrusive and extrusive, during Niobrara and Pierre epochs of the Cretaceous, was probably accompanied by considerable faulting. This epoch of movement may reasonably be assumed during Pierre time if the Anacacho limestone is considered to be a shore-line deposit.

However, it is sufficiently obvious that the Balcones escarpment as such, as well as topographically high blocks of the fault zone, experienced fault movements at a time or times much later than the Cretaceous, unless, indeed, these features have been "resurrected" through a relatively recent stripping of an extensive Tertiary cover.

The regional history affords a foundation for discussion of this problem. The first great change in depositional history of the Tertiary came between the Oligocene and the Miocene, between epochs of marine deposition in the Eocene and Oligocene and a long history of prevalently non-marine conditions inaugurated with the Miocene deposits and continuing until the present. The upper part of the Coastal Plain and

Edwards Plateau Cretaceous seems to have been first extensively eroded during the Miocene, since Miocene deposits are the first in which have been found plentiful, re-worked, Cretaceous fossils and sediments. It is pertinent to notice that none of the many cherts of the Edwards Cretaceous is found in Miocene or early Pliocene deposits, although large Cretaceous fossils are rather plentifully distributed through Miocene sediments. The greatest change in the Cenozoic occurs at or near its end and is marked by the deposition of the Lafayette, the coarsest of all the coastal Cenozoic sediments, which also marks an abrupt change between predominantly fine underlying and predominantly coarse overlying deposits. Lafayette and later sediments are entirely absent from the Edwards Plateau but are present throughout the area south of the Balcones escarpment, which forms the southern and southeastern margin of the Edwards Plateau. Furthermore, the Lafayette bordering the Balcones escarpment is entirely composed of chert and limestone gravels, silts, and other materials of the Lower Cretaceous rocks forming the Edwards Plateau. The probability, therefore, is that the Edwards Plateau was first actively eroded at the beginning of Lafayette time, because of an abrupt upwarping or upfaulting at that time along the Balcones escarpment and fault zone.

The present position of the Balcones escarpment very closely coincides with the fault lines. The facts that the escarpment has not receded farther from the fault zone, that the Edwards Plateau is maturely dissected only in a narrow strip contiguous to the fault zone, passing a short distance farther back into a relatively flat uneroded surface, and that south of the main escarpment blocks of the more resistant rocks still form topographic prominences, all indicate the relative recency of the faulting or warping.

The relatively very great amount of post-Lafayette erosion also indicates relative recency of movements. This is well shown in the area bordering the Balcones escarpment on the south, particularly from the vicinity of San Antonio westward to the Rio Grande. At the base of the escarpment, the Lafayette and succeeding Port Hudson deposits merge imperceptibly into each other at the same levels, but within a few miles gulfward the difference in level between the two is as great as 200 feet or more. Also, the lower Port Hudson deposits become miles in breadth. Consequently there can be no doubt that the Lafayette was very greatly eroded before the deposition of the Port Hudson. The Port Hudson in turn is considerably dissected along the valleys of the coastward-flowing streams. Erosive activities since the beginning of the Lafay-

ette therefore seem to have been sufficient to make all the present erosional topographic features of the Balcones fault zone. The converse is also true, namely, that the amount of erosion suffered by the Balcones fault zone and escarpment and the adjacent section of the Edwards Plateau is no greater than that of other and similar areas during the Pleistocene alone. If the topography of the Edwards Plateau and Balcones fault zone were a "resurrected" one, some remnants, at least, of Tertiary capping should still persist on the extensive interstream flats of the Edwards Plateau. There should also be detritus from such remnants in the Lafayette or some older Cenozoic formation. Since the Lafayette is the earliest formation containing detritus from the Edwards Plateau formations, it is probable that the origin of the Balcones scarp as a present topographic feature is contemporaneous with the Lafayette.

Stratigraphic distribution of asphalt.—Most of the asphalt is found in the Anacacho limestone. There is also a considerable amount in the upper part of the Pulliam formation, saturating a 5-foot bed of soft sandstone for a distance of at least 3 miles along Nueces River from Black Waxy Falls downstream. The average content of asphalt in this sandstone is approximately 12 per cent. The overlying bed of sandstone, 10 feet thick, contains some asphalt. The asphaltic sandstone occurs in a shallow syncline with a fault crossing the river at Black Waxy Falls and another visible fault 3 miles down the river at the lower end of the asphaltic outcrop. Drilling and other investigations have demonstrated the presence of asphalt or heavy tar in porous beds in every other formation of the entire Cretaceous section of the area, especially in the limestones and serpentinized or chloritized parts of the igneous rocks. Some of the igneous rocks seem to be submarine lava flows and tuffs. The youngest rock cut by the intrusions is the Pulliam formation of the Upper Cretaceous.

THE ANACACHO LIMESTONE

The Anacacho limestone crops out for 100 miles east and west, its eastern limit being approximately the Bexar-Medina County line and its western limit the west end of the Anacacho Mountains at a point about 7 miles east of Spofford Junction, Kinney County. It may extend even farther west, possibly being faulted out of sight and covered by later deposits for some distance beyond the west end of the Anacacho Mountains.

The formation is about 200 feet thick at its eastern end, increasing to 400 feet in central and western Uvalde and eastern Kinney counties and decreasing to 300 feet at its western visible limit.

The Anacacho is mainly a coarse-grained yellow limestone, whitish on weathered surfaces. Its western part is more solid limestone, containing some marly beds. The limestones are locally clayey and in some places sandy. On Blanco River, west of Sabinal, the Anacacho contains some fossiliferous marine and basic igneous materials. It becomes more sandy and clayey eastward in Medina County where the limestone contains some coarse sand. East of Medina River, the greater part is much finer and more sandy. The asphaltic limestone in Medina County is underlain by clay or chalk and is overlain by 5 feet of glauconitic marl, succeeded by an organic conglomerate composed of masses of *Gryphaea vesicularis*. In the western part of its outcrop in Kinney County, it is underlain by a thin bed of Pierre (Upson) clay or marl. There are some sandy layers under the Anacacho limestone at its west end. The Anacacho is overlain by shallow-water terrigenous deposits of the Fox Hills (lower Escondido). The Anacacho limestone is more resistant to erosive agencies than any of the other Upper Cretaceous formations, hence its outcrops form topographic prominences.

A marked characteristic of the Anacacho in many places is cross-bedding. The bulk of the limestone is made up of comminuted shell fragments and it is judged that these coquina beds are more prevalent than is indicated by surface outcrops, since surface weathering processes consolidate them into denser rock. The limestone consists of broken particles of shells and plates and spines of various organisms, particularly of sea urchins, mollusks, corals, rudistids, and small tests of foraminifers. Thick shells such as oysters, turritellas, and rudistids are less broken. The rock has been consolidated by partial solution, re-deposition, and introduction of calcium carbonate. Exactly similar coquina is formed along shore lines to-day where little or no terrigenous detritus is brought in from the land, such as the coasts of southern Florida, Yucatan, the east coast of the Gulf of California, the tropical barrier and fringing reefs and shallow shoals. There can be no doubt that the Anacacho is a beach or barrier-reef deposit. The sea bottom during the time of its deposition was very slightly submerged. It may not have been the actual shore line of the Pierre sea, but if not, was probably a shoal the surface of which was brought close to the surface of the water by progressive uplifts concomitant with the volcanic eruptions then taking place.

ASPHALT CONTENT OF THE ANACACHO

The porous coquina limestone of the Anacacho is, as a rule, filled with asphalt. This is certainly the condition, at least, in proximity to

the many faults and igneous basaltic masses. It is only exceptionally that the asphalt content is indicated at an exposure, since the outer surfaces of freshly-quarried rich asphalt rock become white after being exposed for a few months. In natural exposures, the thickness of the oxidized zone of the rock, barren of asphalt, ordinarily ranges from 6 inches to 10 feet. Wells drilled south of the outcrop in Medina and Uvalde counties generally find heavy tar or asphalt in the Anacacho. Asphalt rock is, moreover, known from one end to the other of the Anacacho outcrop.

The total content of asphalt is undetermined, but a computation based on certain assumptions is illuminating. The known asphalt content is as much as 25 per cent and in fresh natural or artificial exposures the average asphalt content is at least 10 per cent. It is certainly a conservative estimate that on the average the rock which is 10 per cent asphalt is only 10 feet thick. The further assumption that there are only 100 square miles of rock containing asphalt in that quantity, is probably also conservative. The total asphalt content, on such assumptions, is very nearly 500,000,000 barrels. This figure does not take into account any of the asphalt found in the other Cretaceous formations.

POSSIBLE SOURCES OF THE ASPHALT

The asphalt may have been derived from the marls or clays of the Pierre into which the Anacacho passes southward down the dip. This source does not seem very probable for the asphalt in the Trinity Cretaceous, especially since the intervening Edwards limestone is an important carrier of artesian water. It is improbable that the asphalt has originated in the Anacacho itself.

The underlying formations from which it is more probable the asphalt has been derived include the Benton (Eagle Ford), which is very bituminous and increases in thickness westward and southwestward from 30 feet in central Medina County to 250 feet in central Kinney County. A considerable thickness of dark shales underlies the basal Trinity Cretaceous in Uvalde County. Neither of these two formations, nor the Pierre clay, is known to have important porous beds such as are present, locally at least, in the Glen Rose, Edwards, Georgetown, and Buda limestones and the Austin chalk, all of which exist underneath the Anacacho. There are also very bituminous black shales, in the Lower Cretaceous (Edwards).

F. M. Getzendaner has made a study of the veins of the region. He finds three generations of minerals. The outer walls and the wall

rock have a coating of asphalt. The middle layer is marcasite, with at least a small amount of chalcopyrite. The core of the veins is calcite. This is suggestive of the following course of events: (1) a time of asphalt "deposition" or "intrusion" followed by (2) deposition of sulphides, perhaps largely because of reduction of aqueous sulphate solutions of the metals by the reducing action of the asphalt, the vein formation, ending with (3) deposition of calcite from carbonate waters. Sulphates and sulphurous gases corrode limestone, liberating large amounts of carbon dioxide, which in turn dissolves additional limestones. The sulphides in the veins are entirely unaltered. It is well known that sulphate water or hydrogen sulphide gas "tarrifies" petroleum and forms asphalt.

The volcanoes of Italy and the Andes emit mainly hydrochloric acid, hydrogen sulphide, and sulphur dioxide gases. At Santorin are also small quantities of hydrocarbon gases, and it has there been shown beyond reasonable doubt that water has been dissociated into its elements in the central heat of the volcano. In Italian volcanoes, carbon dioxide appears as the intensity dies away. At Mont Pelée, Martinique, the recent gas is notably charged with combustible substances. Hydrocarbons, as well as notable quantities of sulphur dioxide, are probably present in Kilauea gases. There is high percentage of hydrogen sulphide in the Mt. Katmai, Alaska, gases. The most conspicuous of all the volcanic sublimation products is undoubtedly native sulphur. Hydrogen is a very plentiful volcanic gas; in fact, it and the carbon oxides are the predominant gases generally occluded in rocks. Ferromagnesian rocks have the largest quantities of occluded gases.

According to F. W. Clarke,[1] volcanic gases issue in an eruption in a certain regular order:

> First. The gases issue from an active crater at so high a temperature that they are practically dry. They contain superheated steam, hydrogen, carbon monoxide, methane, the vapor of metallic chlorides, and other substances of minor importance. Oxygen may be present in them, with some nitrogen, argon, sulphur vapor, and gaseous compounds of fluorine.
>
> Second. The hydrogen burns to form more water vapor, and the carbon gases oxidize to carbon dioxide. From the sulphur, sulphur dioxide is produced. The steam reacts upon a part of the metallic chlorides, generates hydrochloride acid, and so acid fumaroles make their appearance.
>
> Third. The acid gases of the second phase force their way through crevices in the lava and the adjacent rocks, and their acid contents are consumed in effecting various pneumatolytic reactions. The rocks are corroded, and where

[1] "The Data of Geochemistry," 5th Edition, *U. S. Geol. Survey Bull.* 770, 1924.

sulphides occur hydrogen sulphide is set free. If carbonate rocks are encountered, carbon dioxide is also liberated.

Fourth. Only steam with some carbon dioxide remains, and even the latter compound soon disappears.

It is observable that in the hottest and most active phase at the surface, hydrogen and methane are not destroyed, and that sulphur and carbon compounds persist as gases until near the end of volcanic activity. Water is dissociated into its elements in the most active stage, and these elements may combine with carbonaceous matter, at least at some distance from the molten magma, to form hydrocarbons. Beneath the surface the hotter stages last much longer; consequently, they probably exert more action. If the igneous rocks intrude bituminous and carbonaceous sediments—the actual situation in the Balcones fault zone—it is probable that a large quantity of oil, much of it perhaps intermediately in the form of different gases, is distilled from the sedimentary rocks. These gases accumulate and condense in the more porous rocks. The action of sulphur compounds "tarrifies" the oil, giving it generally a high asphalt and sulphur content, and also making it heavy. Oils thus formed are in a sense pathologic.

In this particular area, the Benton alone contained sufficient bitumen to form all the asphalt, provided it could be freed from the rocks. Heat is the most favorable agent for the distillation and this heat was certainly supplied during the igneous activity. At the prevalent depths underground, it is practically certain that there was a deficiency in the amount of oxygen necessary to support combustion. The depths were below the zone of oxidation. Basic rocks, such as basalt, have a low point of fusion and are low in oxygen content. All the Cretaceous rocks of the intruded section contain large quantities of calcium carbonate and if subjected to igneous heat, carbon dioxide, a non-supporter of combustion, would probably be liberated in large amount.

THE DEPTH OF THE BASE OF THE TRINITY SANDSTONE AND THE PRESENT ATTITUDE OF THE JURASSIC PENEPLAIN IN SOUTHERN OKLAHOMA AND SOUTHWESTERN ARKANSAS[1]

FRANK A. MELTON[2] and F. H. McGUIGAN[2]
Norman, Oklahoma

ABSTRACT

Projected profiles of the Jurassic peneplain north of the outcrop of the Trinity sandstone in Oklahoma and Arkansas are combined with subsurface measurements of the base of the Trinity sandstone, and maps are drawn. The present slope of this peneplain and its major flexures are illustrated.

Figure 1 is a contour map showing the present attitude of the Jurassic peneplain in southern Oklahoma and adjoining states. South of the edge of the Comanchean Trinity sandstone this map shows the elevation of the base of the Trinity, since this formation rests directly on the deeply eroded Paleozoic rocks of the peneplain. The data for the attitude of the peneplain where it lies buried beneath the overlapping Comanchean sandstone are taken from about 35 wells, the locations of which are shown by small crosses in the figure; and from elevations at the outcrop. Judging from the way the contours swing south at the western end, it is clear that the area shown is the north limb of a broad plunging syncline, the axis of which extends approximately northwest and southeast. The slope south of the outcrop gradually increases from west to east. It is at its minimum west of the Criner Hills in Love County, and at its maximum at the Oklahoma-Arkansas state line. One of the outstanding features of this surface, and also of the base of the Trinity sandstone, as is well known, is the Preston plunging anticline, the axis of which extends southward 60° E. from the Criner Hills south of Ardmore.

The north edge of the Trinity sandstone, however, is an erosional edge, and this formation formerly extended an unknown, but probably small, distance farther up the slope of the Jurassic peneplain. If rem-

[1]Manuscript received by the editor, July 10, 1928. The writers are indebted to H. C. Vanderpool of the University of Oklahoma and to R. A. Birk of Ardmore, Oklahoma, for many of the subsurface measurements of the base of the Trinity sandstone which are used in this paper.

[2]Department of geology, University of Oklahoma. Introduced by Charles N. Gould.

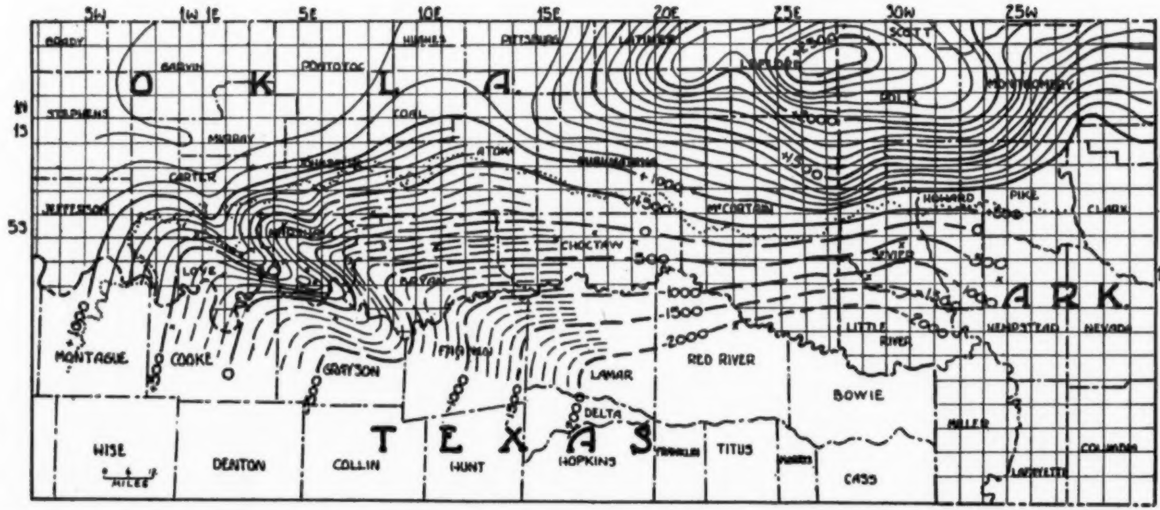

FIG. 1.—Contour map of the Jurassic peneplain in southeastern Oklahoma, southwestern Arkansas, and the extreme northern part of Texas. The heavy dotted line near the +500-foot contour is the north edge of the outcrop of the Trinity sandstone. South of this line the contours represent the buried peneplain—or the base of the Trinity. North of this line the contours are drawn on the tilted and arched upland surface which, in part, has been uncovered by erosion. The sharp nose at the left is the Preston anticline. A broad syncline extends northward into Oklahoma, in Coal and Atoka counties. This is directly between the Arbuckle and the Ouachita mountains. The crest of the arched Ouachita Mountains is seen to be higher than +2,600 feet at the extreme north. Contour intervals are 100 and 500 feet. Small crosses indicate the location of wells where subsurface measurements of the base of the Trinity sandstone were made.

nants of the resurrected erosion surface can be found sufficiently well preserved north of the Trinity outcrop, it should be possible to determine the attitude which the base of this formation formerly had in this region, at least since late Tertiary time—the attitude which it would now have if the Trinity sandstone were restored to its former extent. Since the rocks underlying the Trinity are folded and somewhat metamorphosed Paleozoic rocks, to say nothing of pre-Cambrian granite, they are more resistant to erosion, in general, than the Trinity, and such uncovered remnants of this peneplain are common.

To determine as accurately as possible the slope of this resurrected surface, projected profiles were made at fourteen different places—ten in southern Oklahoma and four in southwestern Arkansas—from topographic maps of the United States Geological Survey. The location of these profiles is shown in Figure 2.

The projected profile[1] has many valuable uses, not the least of which is the restoration of old surfaces of erosion which have been raised and dissected by stream action. The *linear profile* is made from topography along a single line; the *projected profile* is made from the topography of a strip of chosen width. In determining the slope of this surface strips 3 and 6 miles wide north of the Trinity outcrop were chosen, and the highest points of this topography were projected on cross-section paper. The result is a horizon view of the upland surface at an earlier stage in its history than the present. The chosen strips should, of course, extend directly at right angles to the strike of the upland surface measured, but in the location selected north-south profiles involve very little error, since the strike of this peneplaned surface, except for small variations, is nearly east-west. These profiles, combined with the subsurface measurements farther south, make it possible to present a clearer picture of the attitude of the base of the Trinity sandstone and the position of the uncovered Jurassic peneplain than would be possible if either were neglected.

The profiles and cross sections shown by Figure 3 represent a careful combination of these data. The heavy lines of the cross-section paper represented 2 miles horizontally, but only 500 feet vertically. The vertical scale is thus 21.1 + times the horizontal scale and all the slopes are exaggerated by this amount. The solid black line indicates the land surface as it stands at present. The dashed line shows the Jurassic peneplain. The latter crosses the solid line at the outcrop of the basal Trinity

[1]The projected profile has previously been used very effectively by D. W. Johnson of Columbia University.

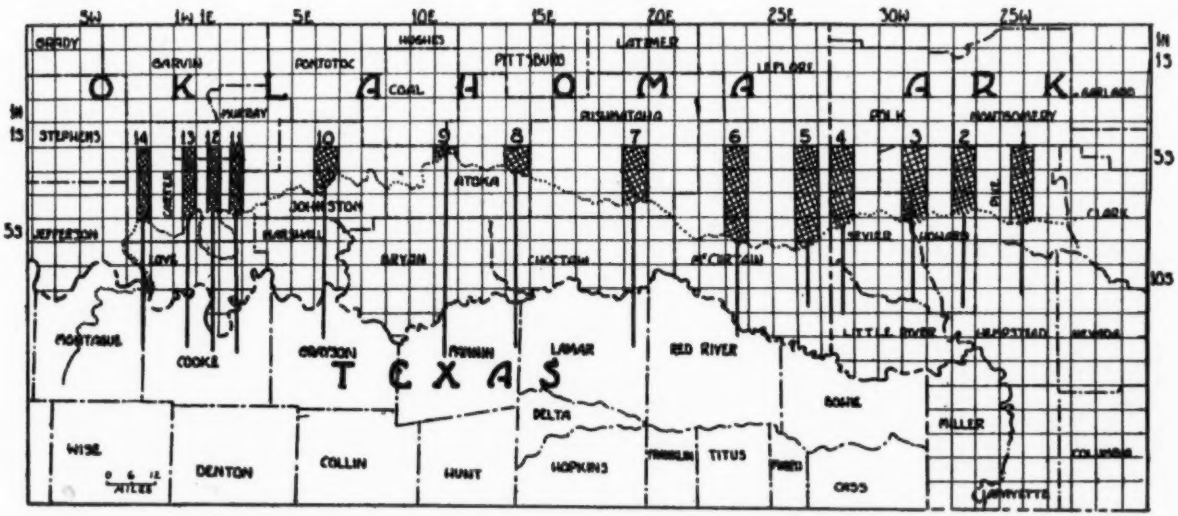

FIG. 2.—The location of 14 projected profiles in southern Oklahoma and southwestern Arkansas north of the edge of the Trinity sandstone are shown, as well as 14 linear cross sections south along this line. The line representing the outcrop of the basal Trinity beds is apparent.

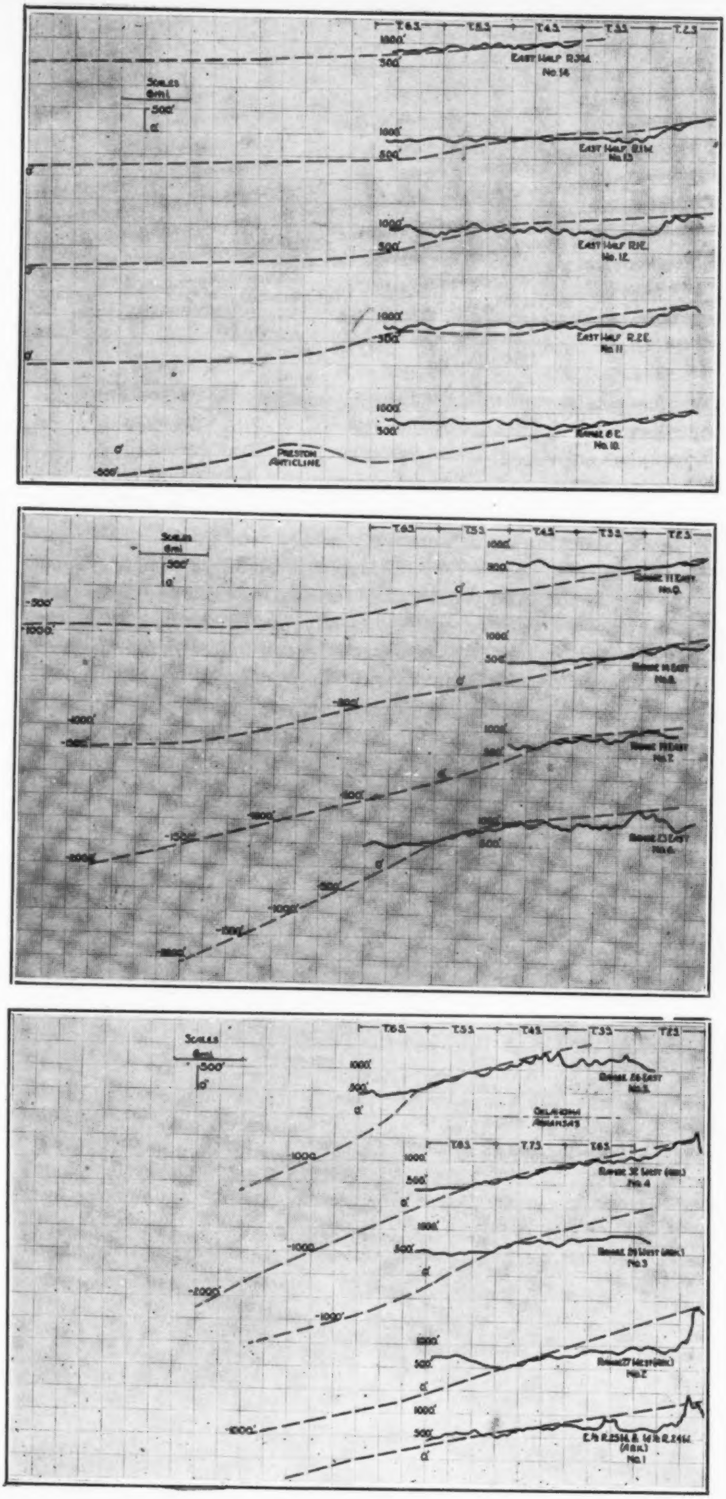

FIG. 3

FIG. 3.—The sections which are here numbered from 1 to 14 are partly projected profile of the land surface and partly true linear cross section. Looking west. The heavy unbroken lines represent projected profiles of the present surface for different distances on both sides of the edge of the Trinity sandstone in southern Oklahoma and southwestern Arkansas. The heavy dashed line represents the Jurassic peneplain. At the right (north) of the edge of the Trinity sandstone this surface has been dissected by erosion. At the left (south) it lies buried at the base of the Trinity. Horizontal scale in miles; vertical scale in feet. The vertical scale is 21.1+ times the horizontal. The basis for these sections south of the outcrop is the contour map shown in Figure 1.

sandstone. At the left (south) of this intersection, the dashed line represents the base of the Trinity, and at the right (north) it marks the restoration of the uncovered peneplain.

Although the profiles of the topography on the right of the outcrop were made from strips of different widths, the cross sections on the left were made along lines which are the southern extensions of the median lines of each strip. These lines are shown in Figure 2. The elevations for the base of the Trinity were taken directly from Figure 1; the accuracy of Figure 3 depends directly, therefore, on the accuracy of the former. Figure 1, in turn, was constructed from limited data—about 35 well measurements of the base of the Trinity—the accuracy of which the authors accepted on faith. Admittedly, they are not sure of their data so far as they pertain to subsurface determinations of the depth of the basal part of the Trinity sandstone. However, if the care and discrimination with which oil companies in general select such data as these may be any guide, the accuracy of the map may be confidently assumed.[1]

The outstanding features of the profiles and sections of Figure 3 are as follows.

1. In half of the sections platted, the peneplain shows no marked flexure or bending at the edge of the present outcrop. Sections 1, 2, 8, 9, 10, 13, and 14 illustrate the condition.

2. The other seven sections, however, show more or less marked flexures of the peneplain near the present outcrop. Sections 11 and 12, which cross the Criner Hills and the Preston anticline, show fairly distinct bends in this vicinity. Sections 3, 5, 6, and 7 show a pronounced bending of the peneplain near the point where it plunges beneath the Trinity sandstone. Sections 5 and 6, in particular, have the sharpest curves. All of these four sections are located on or very near the structural center of the Ouachita Mountains, as shown by the geological map

[1]The senior author at the University of Oklahoma will be glad to enter into correspondence regarding any subsurface determinations which may have been omitted from Figure 1. The ever-present necessity of revising this map as new data are found is fully realized.

of Oklahoma. If the closely folded older Paleozoic terrane of McCurtain County, Oklahoma, be regarded as the structural center of the Ouachita Mountains along the north edge of the overlapping Trinity sandstone, Sections 3, 4, 5, 6, and 7 are centered about this structural core.

3. The most rapid change of slope—the sharpest flexure—shown by the sections is seen on No. 10 where it crosses the Preston anticline in southern Marshall County.

4. The most gentle and uniform slopes are found in Sections 13 and 14, at the western end of the outcrop in Love County, Oklahoma. However, these slopes are not the true slopes of the base of the Trinity here, since they are taken on north-south lines instead of lines at right angles to the strike of this surface. In Section 14 the south slope along the north-south line near the outcrop is about 20 feet per mile.

Except for the influence of the Preston anticline, which causes sharp local deviations, the slope as shown by the sections gradually becomes steeper toward the east, until in Section 5 near the Oklahoma-Arkansas state line the base of the Trinity plunges basinward at the rate of 250 feet per mile. Dips as great as 300 feet per mile are reported from the Comanchean rocks on the south side of the Preston anticline by Stephenson.[1]

Caution is again urged in interpretation of the profiles and cross sections, as the degree of slope is exaggerated 21.1 + times. The amount of change in elevation in feet per mile can, however, be read from the sections directly.

PROBLEMS RAISED BY THE PROFILES AND CROSS SECTIONS

Slope.—The present slope of the base of the Trinity and the Jurassic peneplain south of the Ouachita and the Arbuckle mountains was probably established mainly by two different episodes of tilting, though the relative importance of these mildly diastrophic movements as manifested in the existing slope cannot be accurately determined at present. The variable factors are too numerous.

The first of these episodes of tilting occurred near the end of the Jurassic period and furnished the basin for the advancing Comanchean sea at the same time that it arched the Ouachita Mountains on the north. The Arbuckle Mountains may or may not have been slightly arched at this time. The second episode of important tilting possibly occurred at the end of the Cretaceous period, if we reason by analogy from the arch-

[1]L. W. Stephenson, "A Contribution to the Geology of Northeastern Texas and Southern Oklahoma," *U. S. Geol. Survey Professional Paper 120-H*, 1918.

ing of other mountainous masses and domes in eastern and central North America. The occurrence of the Laramide revolution at this geological interval is a cogent reason for placing a considerable uplift at this time.

However, there is considerable evidence in southwestern Arkansas, as Miser[1] has shown, for believing that one of the major episodes of tilting occurred in the interval between Comanchean and Cretaceous times. At the extreme east end of the area considered in this paper the entire Comanchean section is bevelled by pre-Woodbine erosion and the beds of this formation overlap onto the Paleozoic rocks of the mountains. Furthermore, volcanic activity was in evidence at the very edge of the coastal plain sediments from Pike County, Arkansas, eastward, before, during, and after the deposition of the Woodbine sandstone. The tilting and depression which brought about the overlap of the Woodbine and Tokio sandstones was certainly of major importance from Pike County eastward in Arkansas. The exact magnitude of the tilting in the interval between Comanchean and Cretaceous time, however, is questionable even in Arkansas, and especially from Pike County westward into the area considered in this paper.

In addition to these possibilities the slope shown by these sections may have been imparted to the peneplain in part by further arching of the Ouachita Mountains or further depression of the depositional basin, or both, during the Tertiary era. Present evidence does not justify excluding this possibility.

Flexures.—Concerning the time of origin of the prominent *flexures* of this peneplain (if, indeed, this subject may be separated from that of *slope* previously considered) even less may be said with definiteness than in the preceding discussion.

1. If the prominent flexures observed in several of the sections near the edge of the Trinity sandstone were formed at the same time as the pronounced Preston anticline, the time of origin must have been post-Cretaceous, since the beds of this system are affected by the Preston anticline. In this event, the arching was probably accomplished near the end of the Cretaceous period, reasoning again from analogy with other anticlinal uplifts in central North America. So far as the writers are aware, however, the possibility of flexing later in the Tertiary era can not be definitely excluded.

2. If the Preston anticlinal folding did not occur simultaneously with the development of the flexures under consideration, the determina-

[1] H. D. Miser, "Lower Cretaceous (Comanche) Rocks of Southeastern Oklahoma and Southwestern Arkansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), No. 5, pp. 443-55.

tion of their age is a much more complicated matter. At all events, the solution will not be given in this paper; the problem is merely pointed out as unsolved but probably not insoluble.

The following are possibilities as to the time of origin of the pronounced flexures near the edge of the Trinity outcrop in the Ouachita mountain region (sections 3, 4, 5, 6, and 7). The flexures were produced (1) just before or during the time of deposition of the Trinity sandstone and other Comanchean beds, or (2) in the interval of relative uplift and erosion between Comanchean and Cretaceous times, or (3) during early Cretaceous time—the time of volcanic activity and subsidence east of Pike County, Arkansas, or (4) at the end of the Cretaceous period, or (5) at some time during the Tertiary era.

The writers favor the view that these flexures were formed during or immediately after the deposition of the Comanchean series, though the possibility of their formation during or just following the Cretaceous period deserves further careful investigation. The reason for this preference is the proximity of the flexures to the present edge of the Trinity sandstone. The cause may have been deep-seated and diastrophic, but studies in the recently deglaciated regions of North America and Europe point to the possibility of isostatic or elastic adjustment manifested as marginal sinking, due to the weight of the deposited beds.

The writers do not take the position that the basin which the Comanchean sea invaded, and in which many hundreds of feet of sediments were laid down, was caused by the weight of the sediments. The formation of this basin, as well as the arching of the old mountain mass at the north, was doubtless a result of diastrophic movement with a deep-seated cause; but once it was formed and nearly filled with sediment, the accumulated weight may well have caused additional slight adjustments at the northern margin which steepened the beds and the base on which they rested. The thickest Comanchean sections are found south of the structural center of the Ouachita Mountains.

The late Pleistocene subsidence of eastern North America and northern Europe is now fairly definitely attributed to the weight of the overlying ice. The minimum thickness of the ice sheets where the depression was greatest, may conservatively be placed at 3,000 feet. The weight of 3,000 feet of glacial ice is about 160,000 pounds per square foot. This is nearly equivalent to the weight of 1,000 feet of granite of density 2.7 and approximately equal to the weight of 1,100 feet of sandstone of density 2.5. The weight per square foot of the Comanchean sediments in northern Louisiana, eastern Texas, and southern Arkansas and Okla-

homa is thus seen to be as great as, or greater than, the weight of 3,000 feet of glacial ice. The area where the Comanchean beds are thickest, however, may not be greater than 15,000 or 20,000 square miles, as opposed to several hundred thousand square miles of glacial ice which collected in northeastern North America during the Pleistocene.

It is admittedly not certain that slight subsidence is due to weighting, but the very common, abrupt flexure which is generally convex upward just mountainward from the Trinity outcrop, and the larger flexures of Sections 5 and 3, are at least suggestive.

The sharp flexures under consideration could be partly but not entirely explained if the peneplain on the right (north) of the outcrop had been largely formed by the post-Comanchean and pre-Woodbine erosion. This would then involve intersecting erosion surfaces, and the Jurassic peneplain would be completely removed except beneath the Trinity and for a mile or so north of the outcrop. However, this view does not find much favor at present in the minds of the writers for several reasons, chief of which is the conviction that the Ouachita peneplain is remarkably perfect, as peneplains go, and that its formation must have involved prolonged erosion. The question may be answered in the near future by further studies.

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AN ALTERED VOLCANIC ASH FROM THE CRETACEOUS OF WESTERN KANSAS[1]

GEORGE R. PINKLEY[2] and ROBERT ROTH[3]
Tulsa, Oklahoma

ABSTRACT

This report contains a detailed micro-minerological analysis of an altered volcanic ash from the upper Niobrara Cretaceous of Logan County, Kansas. Its identity as an ash is positive, but it is not a true bentonite such as is common in rocks of the same age elsewhere in the west.

The ash extends throughout a considerable area, 2,000 square miles, with remarkable uniformity. It extends through 200 feet of columnar section. Deposition was made during a period of very quiet seas, as evidenced by little disturbance of the thin beds.

The several beds are of use in making a structure map of the area, as they are nearly parallel to the Niobrara-Pierre contact.

INTRODUCTION

It is the purpose of the writers to present the facts in connection with a remarkable geological phenomenon in Logan County, Kansas. These are the results of field work done in the fall of 1927, and laboratory research in the spring of 1928.

The points to be considered are: (1) the presence of beds of altered volcanic ash in the upper Niobrara and lower Pierre in the area mentioned; (2) a summary of reports on similar material from other locations; (3) an analysis of this material; and (4) the value of the occurrence as a stratigraphic marker.

Thanks are due O. E. Stoner, for the use of his ideas and his photographs.

LOCATION

The samples of the material that form the basis of this report were collected from a bed in the Niobrara chalk, about 60 feet below the Pierre contact.

[1]Manuscript received by the editor, July 19, 1928.

[2]217 West 16th Street. Introduced by E. D. Luman.

[3]Atlantic Oil Producing Company, Tulsa Trust Building. Introduced by E. D. Luman.

This Cretaceous bed is exposed along the south side of Twin Butte Creek, a tributary of Smoky Hill River, in southern Logan County, Kansas. The bed can be observed in several places, and the same material occurs in similar beds throughout the section. The creek flows along the north side of T. 14 S., R. 35 and 36 W. This area is south of the Union Pacific Railway and of U. S. Highway 40. The best exposures may be followed from an area south of Oakley in Gove County to the vicinity of Wallace in Wallace County, along the south bank of Twin Butte Creek and both banks of Smoky Hill River.

This includes the west end of the area discussed by Lupton, Lee, and Wallace.[1]

MANNER OF OCCURRENCE

In the southern part of Logan County, Kansas, there are many exposures of the lower 100 feet of the Pierre shale (Fig. 1), and of the

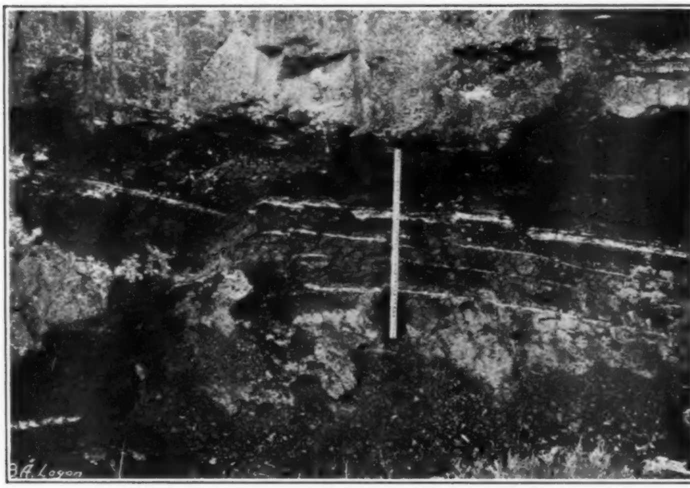

FIG. 1.—"Bentonite" in a faulted zone in Pierre shale. This shows the clear-cut features of the unweathered material. (Photograph by O. E. Stoner.)

upper 200 feet of the Niobrara chalk. As both of these formations are relatively soft it is only rarely that a good exposure of the exact contact is seen. As a result, exact structure mapping is extremely difficult.

[1]"Oil Possibilities of Western Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 6 (1922), No. 2, p. 69.

While working in this area the junior writer found several bands of clay-like material that served as bedding planes in the shale and chalk. As the exact nature of this material could not be determined in the field, samples were taken for laboratory examination. These were examined in detail by Robert Roth, who classified the material as altered volcanic ash or "bentonite." In places this material looks exactly like ordinary laundry soap and was called "Soap" in the report written on the area. It varies in color according to the length of time it has been exposed to the process of weathering. When first exposed it is a creamy white, from which color it turns green, and, after long exposure, becomes a rusty brown. This is probably due to the decomposition of the iron-bearing minerals in the ash. The beds are not very thick, 8 inches being the maximum observed. Being much softer than the inclosing chalk, the individual "bentonite" beds are readily discerned on a cliff from a considerable distance (Fig. 2). The "bentonite" in the shale could not be examined as easily as that in the chalk, owing to the lack of good exposures. Figure 1 shows the most prominent bed, which is somewhat dislocated by a near-by fault. The same chalk bed differs in physical appearance, from one exposure to the next, depending on the degree of weathering. The "bentonite," however, is very uniform.

The area extends 50 miles east and west, and 30 miles north and south. It is probable that within an area of 2,000 square miles there is little variation in the beds.

CLASSIFICATION

This material is called "bentonite" in this article, the quotation marks being used because there is doubt about its identity as the true bentonite of the United States Geological Survey. A. W. Giles gives the following discussion of the definition of this material:[1]

> The following definition, taken from the United States Bureau of Mines and published in the *Engineering and Mining Journal*,[2] is typical: 'The name bentonite has been applied to a group or series of claylike materials characterized by an alkaline oxide and alkaline earth content of 5 to 10 per cent, fine grain size, high absorptive powers, and usually very strong colloidal properties.'
>
> The United States Geological Survey[3] has defined bentonite as 'a bedded plastic clay which swells immensely upon wetting.' Spence[4] quotes the United

[1] "Origin and Occurrence of Bentonite," *Jour. Geol.*, Vol. 35, No. 6 (August-September, 1927), p. 535.

[2] Nov. 19, 1921, p. 819.

[3] *Bull. 624*, 1917, p. 356.

[4] *Canadian Dept. of Mines Bull. 626*, 1924.

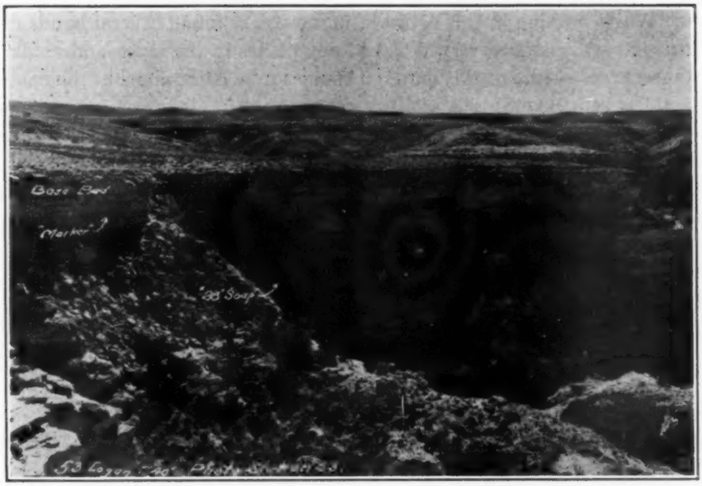

FIG. 2.—Smoky Hill chalk, showing parts of two prominent "bentonite" bands. The band shown as "Marker" is the most prominent one in the area. (Photograph by O. E. Stoner.)

FIG. 3.—A faulted exposure of the Smoky Hill chalk, with a 2-inch band of "bentonite" exposed immediately below the "Base bed." (Photograph by O. E. Stoner.)

States Geological Survey in defining bentonite as 'a transported, stratified clay, formed by the alteration of volcanic ash shortly after deposition.' The alteration is attributed to the hydration of very fine glass particles that have fallen into shallow bodies of water. As hydration progressed, the particles slowly settled out of suspension following flocculation or coagulation.

The fact that it does not swell appreciably when immersed in water is enough to keep it from being classified as true bentonite, but there is not enough difference to merit the use of a new name. It seems, therefore, that this material is only a modified form of bentonite.

SIMILAR DEPOSITS

A survey was made of the literature dealing with the volcanic ash in the western United States to ascertain whether or not anything had been written concerning this area. No previous articles were found, although the Tertiary ash in this region has caused considerable comment. It is also well known that there are many deposits of volcanic material in Mid-Cretaceous rocks in other states.

Twenhofel discusses, in considerable detail, the presence of microscopic volcanic material. He mentions an ash from the Black Hills that was practically free from quartz. This possibly was somewhat similar to the Logan County samples.[1]

Bramlette writes of ash in rocks of Taylor age in East Texas, and in the Annona and Marlbrook formations in Louisiana. In the latter formation an ash carried ilmenite, rutile, brown amphibole, tourmaline, garnet, and secondary calcite. In the Monroe gas field the Annona carries 1,200 feet of volcanic tuffs and lava.[2]

C. L. Baker, speaking of the Panuco oil field in eastern Mexico, says that the formations equivalent to the Pierre, Niobrara, and Benton carry large quantities of volcanics. In the Niobrara there are 300 feet of limestones separated into beds by layers of tuffs ranging from 2 to 18 inches in thickness. In the lower 1,200 feet of Pierre there is considerable tuff, some of which resembles palagonite. It has been derived from an acidic magma containing plagioclase, quartz, and biotite. Most of the crystals have angular, unweathered surfaces. Baker explains the presence of all this material on the theory that it is the result of a series of submarine volcanic explosions.[3]

[1] W. H. Twenhofel, *Treatise on Sedimentation*, Williams and Wilkins, 1927, p. 203.

[2] M. N. Bramlette, "Bentonite in the Upper Cretaceous of Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 3 (May, 1924), p. 342.

[3] C. L. Baker, "Geology of the Panuco Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 4 (April, 1928), p. 395.

MINERALOGICAL ANALYSIS

The sample which has been analyzed was taken from a cliff in a canyon 3 miles southeast of the Kansas City Life Insurance Company's ranch, 18 miles south of Russell Springs, Kansas, and is 65 feet below the Pierre shale. The material has been called soapstone and occurs as partings between beds of Niobrara chalk. In its physical aspects it resembles bentonite to such a striking degree that it was thought that a heavy-mineral analysis might yield interesting results. Accordingly the material was given the usual treatment in order to obtain the light and heavy crops, and slides of each were studied.

During the making of the slide of the light crop it was noticed that the white material turned red when heated in the Canada balsam; consequently, it was very difficult to obtain a slide of the unaltered white material. This tendency to turn red has been noticed many times when altered volcanic ashes were only slightly heated, that is, to 100° C. The presence of an unstable iron compound may thus be inferred. In studying the light crop under crossed nicols the writer observed that the individual grains were anisotropic on the borders, although the central parts of the grains were isotropic and transmitted no light. The refractive index was very low and seemed to be about that of quartz. The whole material appeared to be cryptocrystalline in texture and could not be resolved under a magnification of 350 diameters. A few fragments of strain quartz were observed and also some shreds of sericite. No remnants of any feldspar were observed in the material. A fresher sample might yield these. The whole material closely resembled a deflocculated colloid or clay.

The heavy crop was much more interesting because of the peculiar physical state of the mineral assemblage. Magnetite, in perfect octahedrons showing no abrasion, composed about 80 per cent of the minerals. Its possible source of derivation is from basic and ultrabasic igneous rocks. The perfect crystalline outline shows that it could not have been transported any great distance by surface wind or water. The mineral of next greatest importance is biotite, which is present as the variety phlogopite, and amounts to about 1½ per cent. It is present as tabular short prismatic crystals with the edges showing absolutely no abrasion. This mineral is one of the first to decompose when weathered or transported even short distances. Therefore, it would be very difficult for this mineral to be present in the perfect crystalline form which it has if it were transported by any means other than air currents. No pleochroic haloes or inclosed crystals were observed. The possible sources

are igneous and metamorphic rocks. Zircon prisms were also observed, showing no abrasion and containing many inclusions. The common sources of zircon are acid, intermediate igneous rocks; less commonly crystalline schists and limestones. A few prisms of rutile were also noticed and they also showed no signs of abrasion. The possible sources of rutile are acid igneous rocks and crystalline metamorphic rocks, and not uncommonly it is derived *in situ* from the decomposition of ilmenite.

In considering the possible sources of the minerals observed, it is believed that there is only one way in which the material could have reached its present resting place in its present physical state. It is believed that the material is a partially altered ash derived from a volcano of explosive type somewhere west or southwest of these deposits. This material being blown into the air to a great height was carried toward the east by the prevailing westerly winds and deposited from ash showers periodically over the Cretaceous sea which was depositing the Niobrara chalk of western Kansas.

STRATIGRAPHIC SIGNIFICANCE

The most important discovery in connection with this subject is that of O. E. Stoner, geologist, of Tulsa, Oklahoma. It is that the intervals between the several beds of "bentonite" and between them and the Pierre-Niobrara contact are extremely uniform. It was found by careful measurements throughout an area of 2,000 square miles that this relation did not differ more than 1 foot per mile in any direction. When it is considered that the other rocks in the area cannot be correlated from one outcrop to the next, or across a fault, it will be readily seen that the "bentonite" beds are a tremendous help. It takes considerable time to determine the exact section for an area, but the results are satisfactory. From the manner of occurrence it seems probable that the "bentonite" was laid down in a quiet sea with few currents to disturb the gathering sediments. The thickness of the chalk beds in this area indicates the lapse of considerable time between volcanic disturbances. If, as it is supposed, the prevailing winds in this area were from the west in Cretaceous time, as they are now, it would seem that the source of the ash was at the west or southwest. As there are evidences of volcanic activity all through the Rocky Mountain region, it is difficult to ascribe a definite source to the material. It is hardly likely that the volcanic disturbances in the Gulf area had very much influence on these deposits. In a regional sense, this material is one more link in the chain of volcanic sediments in Cretaceous rocks across the western United States.

CONCLUSIONS

1. The material is an altered volcanic ash, but not a true bentonite.

2. It extends throughout a considerable area, with little or no variation in thickness or stratigraphic position. It covers a fairly thick part of the columnar section.

3. It is of use in structure mapping, after the determination of its position with reference to the Pierre-Niobrara contact.

DISCUSSION

THE OCCURRENCE OF FELDSPAR IN CALIFORNIA SANDSTONES

In the July number of the *Bulletin* two writers discuss the Sespe formation and infer from its mineralogy that it was deposited during a period of aridity or semiaridity. Mr. Reinhart[1] writes:

"The climate that existed at the time of deposition is suggested by the undecomposed condition of the feldspars and other chemically susceptible minerals, and by the red color of the sediments. From these facts it is inferred that the climate probably was warm and semiarid."

Mr. Gianella[2] comes to a similar conclusion, though his study deals chiefly with the heavy minerals rather than with the feldspars:

"The glaucophane, pyroxene, and other more easily abraded minerals from the Sespe formation are remarkably fresh and free from evidence of chemical weathering or long transportation. This feature and the angular nature of most of the grains indicate that Sespe material was accumulated under conditions such as prevail during a semiarid climate......"

At least one earlier student of a California sandstone has attempted to infer climate from the quantity and character of the less stable minerals. In his able study of the Franciscan sandstone, a supposedly Jurassic formation, Davis[3] announced the finding of a high percentage of feldspar, and argued that this formation, too, was probably deposited under arid or semiarid conditions.

In all these discussions there lurks the implied assumption that an ordinary Coast Range sandstone does not have a high percentage of feldspar. If it could be shown that most such sandstones, including some known to have been deposited under humid climatic conditions, are also characterized by a high feldspar content, say 50 per cent, then certainly the arguments cited would need revision. Several investigations of this condition have been made, and the results are surprisingly consistent.

The first petrographic study of Coast Range sandstones seems to have been that of G. F. Becker,[4] whose results have been in print exactly forty years. He was much struck with the feldspathic character of all the Cretaceous and Tertiary sandstones which he studied.

[1]Philip W. Reinhart, "Origin of the Sespe Formation of South Mountain, California," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12 (1928), p. 746.

[2]Vincent P. Gianella, "Minerals of Sespe Formation, California, and Their Bearing on Its Origin," *loc. cit.*, p. 752.

[3]E. F. Davis, "The Franciscan Sandstone," *Univ. California Pub., Geology,* Vol. 11 (1918), p. 30.

[4]G. F. Becker, "Geology of the Quicksilver Deposits of the Pacific Slope," *U. S. Geol. Survey Mono. 13*, pp. 61 *et seq.*

"I cannot recall......a mass of arcose so immense as that exposed in the Coast Ranges."

"The feldspars are often present in about the same quantities as quartz."

Inasmuch as Becker's Cretaceous included the Franciscan sandstone, now generally considered Jurassic, his studies dealt with practically the whole Coast Range section as it is developed in the northern part of the state. His conclusions, though totally neglected by more recent writers, have never been invalidated.

The most recent study comparable to Becker's is that of Woodford,[1] who investigated a series of sandstones from southern California (San Joaquin Hills, in Orange County). He found that a Cretaceous sandstone contained about 40 per cent feldspar; his Tejon (Eocene) samples ranged from 12 to 60 per cent, the average being 43 per cent. Omitting the exceptional sample with only 12 per cent feldspar, there are five that range from 35 to 60 per cent, the average percentage being 49. The Vaqueros (Miocene) sample which he studied contained 63 per cent feldspar, and the Temblor (Miocene) samples had quartz and feldspar "in about equal proportions."

My own unpublished studies, which have dealt chiefly with sandstones from central California, between the areas investigated by Becker and Woodford, corroborate their conclusions. They show, further, that the Pliocene sandstones have about the same feldspar content as the older ones.

So far as known at present, then, the average feldspar content of all Mesozoic and Tertiary sandstones in the Coast Ranges approximates 50 per cent. Sandstones from the Eocene, considered from floral evidence to have been a warm, humid epoch, do not differ appreciably from the normal, or indeed from the supposedly abnormal desert sandstones. That the unstable heavy minerals serve no better as climatic criteria, I have argued in a previous paper.[2]

It should be emphasized, in conclusion, that the data presented in this note are not intended to show that the Sepse and Franciscan sandstones are not desert formations; nor to prove that no feldspathic sandstones exist in California; nor, in the slightest degree, to discourage petrographic investigations of sedimentary rocks. My purpose is simply to bring into more general notice one of the difficulties we meet in attempting to infer from mineralogic data the ancient climates of California.

R. D. Reed

1717 South Third Street
Alhambra, California
August 4, 1928

STRATIGRAPHY OF THE WEATHERFORD AREA, OKLAHOMA

In the July, 1928, number of the *Bulletin*, Mr. Noel Evans published an article entitled "Stratigraphy of the Weatherford Area, Oklahoma." We

[1]A. O. Woodford, "The San Onofre Breccia," *Univ. California Pub., Geology*, Vol. 15 (1925), pp. 159-280.

[2]R. D. Reed, "Role of the Heavy Minerals in the Coalinga Tertiary Formations," *Econ. Geol.*, Vol. 19 (1924), pp. 737-39.

believe this to be an excellent paper in which Mr. Evans clearly states his case. We agree with most of his observations, especially the importance of the post-Cloud Chief-pre-Quartermaster erosional unconformity. We believe the relief of this unconformity to be more than 140 feet. The failure by certain observers to recognize and appreciate this unconformity has caused most of the bad structural mapping of this area.

On one important point, however, we disagree with Mr. Evans. He suggests that certain purple slates and associated laminated dolomites which occur largely in the Caddo County buttes, and are well shown in Sec. 5, T. 9 N., R. 13 W., belong to the Quartermaster formation. It is our opinion that the unconformity in question occurs, in these exposures, above these slates and dolomites and at the base of the impure brecciated dolomitic limestone which caps many of these buttes.

Our criteria for this conclusion are here given.

1. *Stratigraphic.*—As previously stated, the relief of the post-Cloud Chief erosional surface is more than 140 feet. The first sediments to be deposited on such a surface would normally be conglomerates and breccias. Such breccias and conglomerates occur locally, but everywhere in association with the impure dolomitic limestone and definitely above the slate and laminated dolomites. It is difficult to conceive of a condition that would give rise to the deposition of the finely laminated slates and dolomites on this surface of high relief *prior* to these breccias and conglomerates. The stratigraphic sequence alone suggests that the slate and laminated dolomites belong to, and are conformable with, the White Horse sandstone section beneath. (Mr. Evans called attention to the unconformity that may be rodded between the dolomite and the White Horse sandstone in Sec. 5, T. 9 N., R. 13 W., as additional proof that the dolomite in question belongs to the Quartermaster formation. Close scrutiny of this contact reveals that the relief of the erosional surface, if such it be, does not exceed 18 inches. We naturally regard this unconformity, if such it be, as a very minor affair compared with the enormous unconformity that occurs after Cloud Chief time. We are inclined to the opinion that this uneven contact of such low relief is the result of some freak of Red-bed sedimentation rather than the result of an active period of erosion prior to the deposition of the dolomite.)

2. *Structural.*—(A) The "frothy" dolomitic limestone occurs in many places above the unmistakable Day Creek dolomite along the west half of R. 14, T. 10 and 11 N. The interval between these two beds is far from uniform, ranging, according to Mr. Evans, from 6 to 58 feet, and, according to our observations, up to 120 feet. At no place where the "frothy" dolomitic limestone is demonstrably unconformable above the (accepted) true Day Creek dolomite does there occur, in association with the upper bed, either a finely laminated dolomite (resembling the Day Creek), or a purplish slate. (B) Wherever the purplish slate and associated laminated dolomites occur, they show, when mapped, a rather regular dip and strike and positions throughout the entire area that tie in altogether satisfactorily with the (accepted) Day Creek dolomite farther west.

Conclusion.—For the foregoing reasons, we believe that the close vertical association of the "frothy" dolomitic limestone and the underlying laminated

dolomite and purple slate of many of the Caddo County buttes is pure coincidence rather than a true stratigraphic association; and that the laminated dolomites and purple slate represent the Day Creek horizon wherever they occur.

HASTINGS MOORE
L. B. SNIDER

TULSA, OKLAHOMA
August 22, 1928

ORIGIN OF THE FOLDS OF OSAGE COUNTY, OKLAHOMA

In the May issue of the *Bulletin*, Volume 12, Number 5, is a paper by Robert Wesley Brown entitled "The Origin of the Folds of Osage County, Oklahoma." Disregarding the author's summary dismissal of various alternative hypotheses that might explain the origin of the folds (and faults) of Osage County, the following points for and against the hypothesis advanced will be here tested by the laws of dynamics.

(1) As regards Mead's classic experiment, only the final result of shear folds is to be observed in the photographs published. Experiments made under shearing stress by the present writer, with different materials, however, produced at first incipient domes with low ratios of major to minor axes. This ratio increased with the angle of detrusion and time factor imposed. The results from these experiments were presented by invitation before a meeting of the Geological Society of America[1] in Los Angeles in February, 1927. Thus the low-dip domes of Osage County having an ellipticity of small eccentricity in plan may well be incipient in their development in so far as experimentation offers an analogy. According to the author, higher dips occur in the older unconformable subjacent folds. The present writer ventures a guess that these domes may be longer in proportion to their width than those described in the younger beds. The fact that the folds lie *en echelon* and the fact that each is traversed at right angles by tensional faults can more simply (and rationally) be explained by shearing stresses.

(2) Dr. Brown states: "Rotational stress develops compressional forces in only two opposing directions and at right angles to this direction there is no compressive force." If the rotational stress be horizontal, as implied, how about the vertical compressive stress (not force) on the lower beds due to the force of gravity? Is this stress not at right angles? Also, what about the external resistance to horizontal elongation produced at right angles to the least axis of strain (Dr. Brown's compressional forces)? May not the internal elongational stresses induced along each fold produce the phenomenon of plunge along the axis of each dome by external resistance to displacement of the same beds beyond the shear zone? Would not this external resistance also constitute a compressive stress at right angles? In his textbook *Structural Geology*, Leith describes three unequal, mutually perpendicular axes of strain so oriented as to express stress differences for any deformed elastic solid under either direct or rotational stress. The author should remember that the axial proportions

[1]The present writer is not a member.

of the strain ellipsoid are determined by the algebraic sum of the external and internal components of stress resolved along three mutually perpendicular directions and that elongation along any one merely indicates a predominance of an extensional over a coincident compressive stress, or vice versa.

(3) In continuation of the previous quotation: "The only type of fold indicating considerable shortening in one direction and none at right angles is a fold indefinitely elongated, which consequently should be the type developed by rotational stress." In paragraph 3 of page 508, does not the author contradict this statement by explaining why long, narrow folds are due to direct compressive stress? An indefinitely long fold would seem likely to have been the product of direct compressive stress normal to the major axis of folding and uniformly transmitted throughout. The length of a fold produced by rotational stress is limited to the oblique width of the shear zone, ordinarily narrow relative to its linear extent. At the end of the same paragraph a modicum of shear is conceded by the author to explain the slight ellipticity of the Osage domes. Why not also include their systematic alignment; their orientation with respect to this system; and the tension faults normal to their greatest axes of strain?

(4) As to the statements, "Domal folds can be produced experimentally by compression from all directions" and "The compressive forces, causing folding in the earth, probably originated as forces acting more or less equally in all horizontal directions......," this the author admits is possible only in highly plastic materials. It is obvious that in rock strata even in the plastico-frangible zone, flowage is a distinctly subordinate manner of failure as compared with its importance in rubber or linoleum. The present writer has not attempted to duplicate the experiment, but knowing that equal radial stresses of horizontal compression would involve circular contraction of the area under such a stress and that the circumferential shortening throughout would be roughly three times the diametric shortening, hazards the guess that yield by flexure of incompressible stratified materials would be radial as well as diametric and that shortening would be taken up by imperfect radial folds having axial plunges away from a common high center.

(5) "The shearing forces alone produced the faults, which probably were formed after the period of maximum intensity of the compressional forces....." Within any shear zone the strain ellipsoid prescribes shortening along the least axis of strain and differential elongation at right angles thereto. Thus shortening and lateral extension are contemporaneous events, and folding normal to tension faults is the response of flexible-frangible strata to the change of surface area imposed by shear. It would therefore seem that "The simplest answer to these questions is that two sets of forces were operative," but not in succession, as propounded by the author.

(6) As to the basins: do they not all lie *en echelon* alternately between the domes? If so, may their origin not be attributed to contemporaneous development with the domes? Flowage of the massive basement rocks from under the stratified basins to form the cores under the stratified domes has its experimental analogy. The deep basement rocks are ostensibly under intense confining stress and in a state of potential flowage that may become an actuality through fatigue and the relief offered by the folding stratified cover. Relief is to be expected toward the so-called tunnel effected below an anticline, and

conditions for the state of flowage toward it would be intensified by the added downward pressure exerted by the forced sinking of the syncline on each side. "The fact that the domes are larger and more numerous than the basins" may have no significance, as it is probably more seeming than real—on the basement floor. There must be a syncline between every pair of anticlines; or, if you will, a basin between every pair of domes. Since the one is merely an inverted form of the other, together they constitute complementary structures that imply a common origin.

(7) Now for the final point—under no less a subtitle than "Some principles of earth dynamics"—to quote: "The compression causing the folds has generally been ascribed to shrinkage of the earth resulting from cooling, molecular rearrangement, or other factors, *all of which act more or less equally in all directions* unless modified by secondary factors such as the crowding of ocean basins against continental segments." The italics are by the present writer. Does the author not remember that any internal shrinkage of the earth involves a corresponding acceleration of its axial rotation—the moment of momentum remaining constant, as it must? Would this not involve a corresponding axial shortening between the poles and a corresponding diametric elongation at the equator? Would not the earth become in itself a strain ellipsoid or, more correctly, a strain spheroid (oblate) in which two of the axes of strain are equal? A moment's consideration of the geometry involved will show that stresses tangential to the earth's surface cannot possibly be equal in all directions as a result of cooling. Between latitudes 45° north and south (approximately) there would be a meridional shortening varying in intensity of compression from a maximum at the equator to zero at the latitude 45° or thereabout. Simultaneously there would be an elongation along all circles of latitude, the intensity of tensile stress varying from zero at the poles to a maximum at the equator. Depending upon the change of volume of the earth's interior, between the poles and latitudes 45° north and south, there would be a progressive extension of all meridians, the stress intensities of which would vary with latitude from a maximum at the poles to zero at latitudes 45°. Assuming dilatation (shrinkage in volume) there is a point attainable (mathematically) where all meridians may become shortened and all circles of latitude extended—an ideal condition for the development of failure of the crust along large-scale shear zones oblique to the meridians. That this may explain continental and oceanic forms by the trends of their coast lines, mountain ranges, and concave deeps, is a possibility for which the present writer is accumulating much structural and dynamic evidence. From such stresses it is possible to explain crustal structure both regionally and locally without recourse to either isostasy or continental drift. As Emmons once remarked, "Geologists should be extremely careful how they associate with mathematics."

HOWARD W. KITSON

THE TEXAS COMPANY
217 HABERFELDE BUILDING
BAKERSFIELD, CALIFORNIA
August 10, 1928

REVIEWS AND NEW PUBLICATIONS

Der Bewegungsmechanismus der Erde. (Processes of Movement in the Earth's Crust). By RUDOLF STAUB, Privatdozent an der Eidgen. Techn. Hochschule in Zürich (Switzerland). Gebrüder Borntraeger, Berlin, 1928. 270 pp., 44 illus., and one map of the earth. 7 × 10¼ inches. Paper. Price, 18 M.

As an open discussion on the theory of continental drift, recently presented before the American Association of Petroleum Geologists, aroused the interest of many geologists, the reviewer feels that a short outline of the author's studies on mountain-building, being so closely connected with continental drift, is here in place. This is justified all the more as the author not only gives a recapitulation of all known ideas on this matter, but presents his own view of the whole mechanism of movement in the earth's crust, which is impressive through its simplicity.

To explain the origin of continents it is necessary to study the causes of mountain-building, which can be observed best in the youngest mountains. The squeezing of the earth's crust into mountains is, in the reviewer's opinion, a proof of continental drift, the principles of which have been stated in Alfred Wegener's theory, though it is necessary to look for additional and more satisfying reasons to explain the whole mechanism of terrestrial mountain-building.

Commencing with the Mediterranean mountain system, the first feature to be noticed is the central part of the whole orogen,[1] originating in the oceanic geosyncline, the Tethys, showing marine sediments and in many places ophiolithic rocks; we then notice marginal mountains, as the Pyrenees, the Caucasus, and others composed of shelf or continental series, belonging therefore to the continental masses bordering the oceanic geosyncline. Every orogenic sector of a geosynclinal mountain-zone shows a main direction of the mountain-building forces which result from the wandering of the more active rearland block (Rückland-Block) toward the more passive foreland, pressing the intervening geosyncline into mountains. Between the geosynclinal and the marginal zones and also within the former are rigid masses, "intra-massives" (Zwischen-Gebirge), which resist compressing forces in a much higher degree, but conduct them into more plastic zones. In connection with the wandering of Indo-Africa toward the old European mass, those continents were forced to split into fragments along a system of meridional rifts, as for instance the African rift-valley and the rift-valley of the Rhine.

The Alpine orogen is composed of several chains. Where they meet each other within a narrow zone, as for example where pressed against a rigid massive, the author uses the term "Scharung," the contrary of a virgation, which

[1]Orogeny, orogenesis: processes of mountain-building. Orogen: the result, the whole mountain system.

we find where chains freely develop into the foreland or where they meet a rigid mass along their strike, forcing them to surround this intra-massive.

The Eurasiatic mountain system shows three well-defined sectors: the orogenic zone of the Mediterranean between the Atlantic ocean and the Armenian "Scharung," western Asia as far as the "Scharung" of Pamir, and eastern Asia between Pamir and the Pacific. The rigid masses of the intra-massives everywhere govern the directions of the chains. Within the flanks of the first sector we see great foreland mountain chains (Pyrenees, Caucasus) which are separated by great intra-massives from the central Alpine chains, whereas in its central part the whole orogen shows an enormous forward movement northward, in the most concentrated form, leading to the gigantic sheet-overthrusting of the Alps. The geosynclinal chains follow the outlines of the old European foreland which in the west and east reached far toward the south, whereas in Middle-Europe its southernmost elements are along the north foot of the Alps and the Carpathians. The great foreland chains of the Pyrenees and the Caucasus, as well as the African rearland chains (Rückland-Ketten), naturally are where in the east and west the old European foreland met at first hand with strong resistance the forces of the north-wandering African continent; therefore, the foreland was highly deformed along secondary zones of weakness. Outside of the real Alpine zone the Alpine movements acted also in a lesser degree on the whole European continental block as far as Scandinavia and the Urals, causing block-faults, horsts, plateaus, and rifts, reviving in part old Hercynic faults and thrust planes.

The second sector of the Eurasiatic mountain system as far as the "Scharung" of Pamir shows first an intra-massive coming in between Tiflis and Kopet-Dagh, surrounded by the Caucasus system and the Alpidan front. Farther on India is to be seen as a sector of the Gondwana block moved from the south to the north, pressing the Alpine system into the enormous "Scharung" of Pamir, associated with a gigantic system of foreland mountains, which show in the Altai Mountains an enormous movement toward the north. West of this northward march of India the whole orogen moves southward into the Omanic depression between Arabia and India. At the west end of the Altai Mountains the Russian block as an intra-massive divides the southernmost chains of the Tianshan system. The branches on the south follow the front of the Alpine orogen into Europe, whereas the main middle branch of the Tianshan system leads over the Urals to Nova Zembla. The enormous power of the Russian block in dividing mountain chains may be observed through the Caledonic and Hercynic epochs of mountain-building, as the mountains of the Alpine foreland follow the zones of folding of those epochs, reviving their lines of dislocation.

The third sector of the Eurasiatic mountain system between Pamir and the Pacific shows first a virgation of the chains where the Indian block is first submerged. Farther east the Indian block recovers its strength for a strong northward push and the chains come together again in the great Indian "Scharung." From there on eastward the Indian block sinks again and the Alpine orogen spreads out again, due also to the presence of the south Chinese and the Sinian rigid masses. The movement is distinctly southward within the whole Burmanic arc between Tibet and Japan, and continues between the rigid masses of India and of the Pacific block, which hold the movement back on its flanks.

The amphitheater of Irkutsk is only the innermost arc of the Sunda arcs. The grandeur of the arc from Tokio to the Mariana Islands and the Moluccas to Java and to Assam definitely indicates a folding of eastern Asia toward the south. As Africa moves northward and Siberia southward, the structure of Asia is the result of a movement of a southern and a northern continental mass toward each other. The latter is stronger in the west, the former in the east. The result is a turning of the whole continental block. Naturally we find the greatest complications where those two blocks are closest to each other, that is, in the Indian sector. At the east end of Eurasia the enormous rigid mass of the Pacific block splits the Mediterranean chains. Their northern part goes through east Asia to Bering Strait, their southern part to New Zealand. The former is built of the central chains of the Alpine orogen, which are coming from central Tibet to Burma and east of Celebes, where they are splitting into three separated chains, one going through south Almahera to the Oceanides, one through Almahera to the Mariana Islands, and one through the Philippines to Japan. The elements mostly south of the Alpine orogen, that is, the Dinarian chains and the rearland chains of Gondwana, do not accompany the central chains toward the north, but go through New Guinea to New Caledonia and New Zealand. The enormous rigid mass of the Pacific block therefore forces the chains of the Alpine orogen to the greatest virgation on earth. The lines of islands of the Australian Oceanides are grouped in great arcs facing the Pacific Ocean, again showing northward movement. The innermost part of this group of arcs is made up of the east Australian coastal chains which are Australian rearland chains, Australia being itself a sector of the Gondwana block.

Looking again at the Pacific virgation, we recognize the central parts of the old Tethys as lateral branches of the Pacific, showing, like its border, a great occurrence of ophiolithic and batholithic series. The splitting of the Alpine orogen by the Pacific block occurs between the northernmost ophiolithic Dinarian and the southernmost Alpiden branches of the geosynclinal central orogen, and therefore along its central ophiolith-axes. The great virgation of the Alpine orogen on the east border of the old world raises the question whether there are not analogous conditions on the west end of the Eurasiatic-Gondwanian continental blocks, that is, in America on the east border of the Pacific Ocean.

In studying American conditions, the author comes to the following conclusions. The North American chains are not connected through the arc of the Antilles with the cordilleras of South America, as previously thought. The Mediterranean orogen passes through the Atlantic Ocean and separates in Central America in front of the Pacific block in an enormous virgation. Its northern part leads through North America toward Alaska; its southern part, through the Andes of South America to Antarctis. The free ends of the whole Mediterranean system tend toward each other in the north at Bering Strait, and in the south in the area of Antarctis. As in Asia and Australia, the geosynclinal orogen is restricted to the Pacific side of the whole system of chains. In North America its chains are separated by great intra-massives reaching from the Wrangel Mountains to the Great Basin from the block of Laurentia, of which the Rocky Mountains constitute its deformed marginal zones. The

intra-mountains of Alaska and of the Colorado plateau force the chains of the Rocky Mountains to great virgations. As the movement of the North American chains generally is toward the west, Laurentia acts as the rearland. North and south of the Great Basin the Rocky Mountains are folded backward over the rearland. A great intra-massive, including the Bermudas, Sargasso Sea, Florida, the Gulf of Mexico, the Mississippi lowlands, and Texas with the Llano Estacado, separates the Appalachian chains from the chains of western America, the Appalachians being an older mountain system, newly revived by the Alpine movement.

In South America we also find great intra-massives between the young chains, although the whole structure is much simpler than anywhere else on earth. In the north the Brazilian block pushes the chains of Venezuela and Colombia in a great arc toward the northwest, but south of Ecuador the rearland on the east underthrusts the Andes, which show sheet folding backward toward the east, over the rearland. The Antarct-Andes do not continue over a southern Antilles arc to the Andes, and the simple tectonics of these chains, as well as the tectonics of the Patagonian Andes, indicate a slow dying-out of the great Alpine movements.

The study of the younger mountains of the earth reveals only one great unit, the Alpine system of the earth, and not a separated Mediterranean and American or east Asiatic system. The face of the earth shows four distinct main units: (1) the young mountain chains of the Mediterranean-Pacific system; (2) the north continent Laurasia (Laurentia and Eurasia) with the Arctic foreland chains; (3) the south continent Gondwana; and (4) the old rigid mass of the Pacific block, which forced the young chains on its east and west sides to enormous virgations. The Mediterranean central system between Antilles and Banda Sea describes a great arc toward the north, its central sector being directly in front of the great northward-pushing African sector of the Gondwana block. The action of the latter was strong enough to split Laurasia, thus opening the northern Atlantic Ocean, which caused the eruption of basaltic magma as found at Iceland, Ian Mayen, Greenland, and all the way to the equator. As strongly as Africa pushes northward, Laurasia, on the weak flanks of Gondwana, moves southward, even between India and Australia and, according to the newest deep-sea maps by Schott and Groll, also in the Atlantic between Gibralter and the Antilles, where the morphologic elements seem to build a great arc toward the south, comparable with the Sunda arc. As a general rule we find indications of northward movement in front of the Gondwanian horsts, South America, Africa, and Australia, and southward movement where Gondwana was submerged, that is, within the South Atlantic and within the Indian Ocean. Besides, Laurasia tended to surround Gondwana in Mexico and within the southern arc of the Mariana Islands, but the Pacific block resisted this movement in its early stage. The rigid Pacific block itself deformed the strike of the northward-moving Alpine chains, which dragged along its flanks, building the chains of Australia and of the Andes in South America. In explaining the greater disturbance of the Alpine chains on the west flank of Gondwana and Laurasia than on their east flank, consideration may be given to Wegener's west drift. But this was not the main movement in the orogenesis of the Andes and of the chains of North America, as those were initiated by the movement

of Gondwana and Laurasia against each other and by the resistance of the Pacific block. The west drift only accentuated the tectonic forces, with a stronger unit of chains as a result. The distribution of the Alpine mountains shows that America did not drift off from the old world, as claimed by Wegener and Argand. Their position in relation to each other was always just about the same. It was not only America that drifted, but the whole Alpine unit, Gondwana, Laurasia, and the orogen between drifted westward. The Atlantic Ocean is not a rift opening behind America as it drifted away from Europe and Africa. It is a depression between the old and the new world which subsequently sank along the rifts, along which both continents split in their strong action against each other. The effect of the west drift on the east side of Laurasia and Gondwana is a zone of weaker Pacific resistance, causing the Alpine chains leading from east Asia and Australia toward the Pacific to spread out toward this zone in great arcs. The island arcs of east Asia are therefore not floats (Schollen) which broke off from the westward-drifting continental masses, but mountain arcs which have been pushed actively eastward toward the Pacific every time the west drift increased in strength, thus causing the Pacific resistance to decrease.

The fact that the lateral branches of the Alpine orogen, especially the American sector but also the mountain chains of New Zealand, Australia, and Japan, had their main paroxysm in Jurassic time, while that of the Mediterranean central segment is of Cretaceous-Tertiary age, seems at first inconceivable. To solve the problem we have to consider that a much larger zone of sedimentation must have been pushed together within the Mediterranean zone than anywhere else. The Mediterranean Tethys must have been much wider than the zones of sedimentation of the Pacific mountains. The facies of the Andean sediments proves that the Andean geosyncline must have been very narrow. In moving against each other Gondwana and Laurasia therefore must have met the Pacific block during a period when they themselves were separated by a wide plastic Tethys. That is why the main paroxysms of the Pacific segments of the Alpine system are older than those of the Mediterranean segment. After their main paroxysm in Jurassic time the former have been in constant deformation until later Tertiary, when the Mediterranean movements also came to a rest.

In the next chapter the author discusses the causes of the Alpine processes of deformation. First, he tries to explain the cause of the enormous rigidity of the Pacific block, which remained continuously in a passive stage, while all the continents were moving as within a frame. It must have a greater density than the surrounding continental blocks, and this is a fact proved by modern geophysics, which also proved a greater Pacific incompressibility, and a greater Pacific coefficient of rigidity and extinction, whereas in these respects the Atlantic proved to have, rather, the characteristics of the continental blocks. The Pacific block must be composed of a homogeneous heavy mass of basic magmas, known as sima. According to Suess and others the earth seems to be built of different shells. The outermost shell is of congealed acid silicates. Beneath this is a highly compressed, latent, plastic, basic zone which assumes the liquid state after the slightest decrease of pressure. This is the source of all the basic magmas. Within this is the metallic nucleus of the earth. We find the

thickest shell of rocks (Steinmantel) within the continents, as a result of the squeezing of the outer crust into heavy tectonic accumulations. Within the geosynclinal zones the thickness of the rock shell is much less.

According to modern petrography salic rocks are differentiated directly from basic magmas. If the magma of great depths is given time for such a differentiation, an acid upper layer separates from a heavy basic lower layer. We find this beneath the heavy continental masses, explaining the predominance of acid material within the continental blocks, undifferentiated magma occurring here only along rifts. But where for some reason a magma comes to an immediate refrigeration, it congeals as a whole to a basic undifferentiated material. This occurs within geosynclinal zones toward which magma of great depths moves fast, congealing to ophiolites, which are wholly typical of geosynclines. The occurrence of ophiolites in the vicinity of the Pacific indicates the basic nature of the rocks beneath the Pacific. But as in the zones underlying geosynclines there is undifferentiated magma, which assumes a liquid state on the slightest decrease of pressure, there must be beneath the Pacific a heavy basic mass, long since congealed to real igneous rock. A primary basic magma zone could not explain the rigid resistance of the Pacific block. Some accident must have brought the undifferentiated magmas of greater depth suddenly to the earth's surface, where they congealed rapidly throughout an enormous area. This may be explained by the theory that the moon separated from the earth in the area of the Pacific, this being the calotte of the longest axis of the tri-axial earth-ellipsoid. After the separation of the moon the basic magma of the earth rushed into this area of highly diminished pressure, congealing rapidly to a heavy undifferentiated basic block. The origin of the Pacific block therefore was caused by the centrifugal force of the earth.

The same power was also the cause of continental drift. Disregarding some secondary characteristics, Gondwana generally moved toward the north and Laurasia toward the south, that is, away from the poles toward the equator. The continents are made up of old—including the oldest—mountains, and represent therefore a thick mass of light material swimming on a latent plastic magma zone of much greater density. These swimming bodies are governed by the centrifugal forces of the rotating earth and are moved as sun spots move from the poles toward the equator. The amount of the centrifugal power must be greater on large masses, and also on masses farther away from the equator. It reaches its maximum between the latitudes of 45° north and south. A paleontological study of middle Europe shows that between Carboniferous and Triassic times it must have been confined to tropical zones. If we try to picture conditions as they were at the beginning of the Alpine orogenesis by unfolding the mountains, we find the north border of the European block at 45° north latitude, but the south border of the African block at 80° south latitude, which confirms the Permian age of the glacial deposits of South Africa. The location of Africa, closer to the pole, indicates a stronger centrifugal component of the African pole flight (Polflucht) from the very beginning, compared with that of Europe. So it seems clear that Africa overcame the weak resistance of the European sector and pushed it also northward. Though Africa passed the equator, it should be noticed that at a more plastic depth Africa is connected with the whole Gondwana block, the center of gravity of which has not even to-day reached the

equator. East Asia moved toward the south; compared with Europe it therefore was farther north at the beginning of the Alpine orogenesis. Flora and fauna of Siberian sediments since Carboniferous time show typical boreal series, as in the northern part of North America. The tendency of the pole flight in North America can be observed positively only within an area west of the Mississippi. The result of this movement combined with a northward movement of the southeast part of the United States is a turning of the whole block toward the west, simulating a westward movement, although really only an interference of north and south movement, strengthened by the west drift. Paleogeographic conditions are in harmony with this. Carboniferous, Permian, and Triassic of the southeast are tropical like the analogous zones of Europe, but these series are boreal in the northwest from Alaska to San Francisco. The central parts of Laurasia therefore seem to have been in tropic latitude and both flanks in the vicinity of the polar circle. This location of Laurasia at the beginning of the Alpine orogenesis explains the weakness of the centrifugal forces within the European center and the relative strength of both flanks. In studying the location of Gondwana before the Alpine orogenesis we find its African center closer to the equator than its flanks, the northern margin of the former being at about 45° south latitude and the south part of the whole mass being situated around the pole. Gondwana's center of gravity was at about 45° south latitude, in the west at 50°, and in the east still farther south. As the center of gravity of central Laurasia was at about 30° north latitude, Gondwana necessarily had a greater pole flight than the Laurasia-European center. The question about the cause which gave Gondwana and Laurasia this location at the beginning of the Alpine orogenesis leads up to the chapter of the pre-Alpine movements of the earth's crust movement.

In an attempt to explain the Permian starting point of the Alpine folding by pole flight and Pacific resistance some difficulties are encountered. Why is there a flat Alpine geosyncline between the north and the south continent, though located on a Hercynic folded zone? Why does the Carboniferous of Europe, which must have been built in the same latitudes as the coal beds at the beginning of Permian and Triassic time, indicate that there was no Permo-Carboniferous pole flight from higher latitudes toward its Alpine starting point within Permian time? In studying the Hercynic mountains of Europe, we find just as within the Alpine mountains of this sector an enormous movement toward the north. The Hercynic chains enter the European foreland between a rigid Podolian and Celt-Iberian block in a manner analogous to that of the Alpine mountains in the Tertiary. This also throws doubt on a European pole flight during or after the Hercynic orogenesis. If the Hercynic orogen of the central sector were unfolded, the coal zones of Europe would fall into the desert zone of the earth, which is absolutely impossible. If those coal zones were brought into a zone 15° north and south of the equator, the block of pre-Hercynic Europe, being north of the geosynclinal coal zone, would be between 10° and 40° north latitude, that is, close to the equator. The fauna and flora of the African block show at this time a position reaching to the south pole. These facts indicate a much greater pole flight of Africa at the beginning of the Hercynic orogenesis, and only a weak resistance of Europe. This seems to have been true also at the beginning of the Alpine orogenesis, leading to a

similar northward movement of the European sector. If an attempt be made to reconstruct the position of Europe in Permian time at the end of the Hercynic folding, that is, to bring the Hercynic coal zones of Europe within the equatorial zone, there would result as compared with its position already figured out for the upper Permian, a difference of 9° latitude, or close to 1,000 kilometers. To explain the facies-difference of the Carboniferous, the Permian, and the Triassic, Europe must have moved to this extent toward the north during Permian time. To provide the space for an Alpine geosyncline with a width of 1,300 kilometers, the author concludes, after thorough study, that not only the north continent but also the south continent moved back toward the pole after the Hercynic orogenesis. How shall an explanation be found for the separation of two continents just pushed together and the appearance of a young geosyncline between?

As is well known, mountains show a lower specific gravity than the adjacent zones. On a larger scale is the geosyncline with a thin crust occurring between continental blocks with an enormously thick crust composed of an accumulation of light crustal parts. This causes the heavier masses of greater depth to drift from beneath the continents to the lateral zones. Every geosyncline therefore shows an excess of gravity as compared with the adjacent continental blocks. Two continents moving by the force of gravitation against each other will press the geosyncline together, building a mountain system, the orogen. The growing mountains, and still more the lighter masses of the heavy continental blocks, will replace the heavier masses beneath the geosynclines, pushing them to greater depth. Those heavier masses will not remain under the abnormally compressed zone under the orogen. After an orogenesis the continental blocks are welded together by the overthrusting and underthrusting of mountains, thus preventing the escape of greater magmatic masses. Equilibrium of these masses cannot be obtained by local intrusion. Therefore the geosynclinal magma can flow only toward the poles, that is, toward zones where the magma of greater depth is released from the enormous pressure of the continental blocks which later moved toward the equator. At the end of an orogenesis this strong subcrustal drift from the orogen toward the poles would tend to pull the continental floats back toward the poles, stretching them strongly on weak points and even splitting them along certain zones. As soon as the centrifugal forces would overcome this drift toward the poles—which created a zone of stretching, that is, a new geosyncline between the continents—the old struggle of the continental blocks would begin again, squeezing the new geosyncline again together. The Alpine geosyncline originated in the post-Hercynic pole drift of Gondwana and Laurasia. By the time that the centrifugal forces of the earth's rotation balanced this pole drift there was already a strong countercurrent at greater depths toward the geosyncline. This, added to the centrifugal forces, helped to overcome a dead point of stagnation between pole flight and pole drift, and caused the continents to move toward the geosyncline. The centrifugal forces thereafter mainly moved the continents toward each other, compressing the geosyncline toward the orogen, until within the magmatic zones pole drift began its counter-action again, building another younger geosyncline. The building of every mountain system, therefore, is the cause of the next orogenesis in creating a new geosyncline.

In the study of the Hercynic orogenesis, facts show that the creation of a new geosyncline is complicated, and that a whole system of stretching zones occurs within and along the peripheries of the Hercynic orogen. The first main stretching zones, following old tectonic lines, build eventually the main geosynclines of the new orogenic system.

In trying to recognize the action of pole flight and pole drift in earlier times, it is first necessary to study Hercynic conditions. The Permian and Triassic volcanic action within, and caused by, the creation of the Alpine geosyncline, as well as the age of the Cape Mountains of South Africa, indicate a continental pole drift as causing the Alpine geosyncline continuing until the end of Triassic time.

In reconstructing conditions as they were before the Hercynic orogenesis, we see that in Laurasia, with the exception of western North America, the same manner of origin existed as before the Alpine orogenesis. We see northward movement with African pole flight in the center, and southward movement with Laurasian pole flight at the flanks of the system. The south movement of Siberia was much more intensive, and reached over a longer front than during the Alpine orogenesis. The north movement of Europe was at least as strong as during the Alpine folding. The result was a much stronger turning of Laurasia toward the right, furnishing an explanation for the absence of Hercynic mountains in western North America, with the exception of Alaska, where the west flank of North America just barely reached the Pacific resistance.

What are the causes bringing the central sector of Laurasia before the Hercynic orogenesis nearer to the equator than its flanks, as was the situation before the Alpine orogenesis? The Hercynic geosyncline had its beginning in early Devonian time, that is, at the end of the Caledonic orogenesis. What is the relationship of the Caledonic mountains and the Hercynic geosyncline? Though the Caledonic mountains of to-day are almost destroyed by the Hercynic and Alpine movements and by erosion, it is still possible to recognize, at least in the northern hemisphere, the main scheme of the whole system. There are two main arcs convex toward the equator, separated by a much less disturbed European middle sector. The west Caledonian arc between Canada and Scandinavia and the east Caledonian arc within Siberia are within the areas where, during Hercynic and Alpine orogenesis, the Laurasian continental block moved south, that is, within the Atlantic Ocean and Siberia. This distribution of the Caledonic main elements is perhaps the cause of the post-Caledonic south movement of the flanks of Laurasia, that is, of a stronger pole flight especially of these segments.

What was the location of the Caledonic mountain system at the end of the Caledonic orogenesis, that is, at the beginning of the Herynic geosyncline?

The foreland of this geosyncline was the "Old-red Continent" extending from America through northern Europe to Siberia. This Old-red zone was developed in the northern sub-equatorial desert zone. Then the central Hercynic geosyncline adjacent to the south must have fallen within the equatorial zone. As the Old-red transgressed the newly-built Caledonic mountains, it is evident that the Caledonic front within Devonian time, that is, at the beginning of the stretching of the Hercynic geosyncline, generally must have been at least within the northern desert zone. Before the deposition of the Old-red and be-

fore the stretching of the Hercynic geosyncline the Caledonic front, therefore, generally must have been very close to, or in part at, the equator. We clearly see that the Caledonic mountains, as well as the Hercynic and the Alpine mountains, were equatorial mountains, as caused by the pole flight of Laurasia. The two main arcs of the Laurasian Caledonides were built in the equatorial zone of that time by the pole flight of the Canadian and Siberian shield. Between these two Caledonic sectors we see the Caledonic mountains in Scandinavia and at the Yenisei in Russia far up in the north. The old Russian block, at that time a part of Gondwana, enters as a separating mass from the south between these two southward-moved arcs, as the African fragment of India to-day pushes itself between the Iranic and Burmanic arcs of the "Alpine" mountains. Compared with the western and eastern Caledonides the area between the Yenisei and Scandinavia shows a much less folding-intensity. As caused by mountain-building pole drift following, the building of the Caledonides therefore must have acted very strongly on the Canadian and Siberian segment of Laurasia, whereas the European center hardly moved. In this is seen the cause of the arching of the Hercynic geosyncline in the area of the European-African central segment. After the Hercynic orogenesis we see the previously separated main centers of Laurasia of to-day, that is, the Canadian, the old Russian, and the Siberian masses welded together along the rising Caledonides. But as the following pole drift acted only on the flanks of Laurasia, the facies of the Hercynic sediments of Laurasia remained typical from Devonian to Carboniferous and Permian, whereas the facies of the two flanks, in Siberia and in the western part of North America, changed to a more and more boreal character.

In summarizing, pole flight and pole drift are seen to dominate the history of the earth from the oldest Paleozoic time until to-day. Pole flight acting separately in the east and west built the Caledonides, pole drift separated the Caledonic block along zones of weakness, originating the Hercynic geosyncline. After an isostatic equilibrium was reached pole flight became dominant again, building the Hercynic mountains. The following pole drift led to the origin of the Alpine geosyncline, which afterward was folded together into the Alpine mountains by another pole flight. To-day we see pole drift again opening another geosyncline within the zone of the Mediterranean. With the drifting of the continents toward the poles and with the stretching of every geosyncline, Gondwanian fragments remained connected with the block on the north. Thus, we see the old Russian mass and the Sinian mass of east Asia remaining connected with Laurasia after the Caledonic orogenesis; the Bohemian mass of Corsica, France, Germany, and Bohemia, after the Hercynic orogenesis; and fragments in India, Arabia and perhaps in the Alps, after the Alpine orogenesis.

Pole drift and pole flight also furnish an answer to the question why the great paroxysms of the earth caused by pole flight always have been separated by orogenetic times of rest, during which pole drift was opening a geosyncline between the continental masses. The cause of all the events renewing the tectonic game repeatedly, that is, the moving of the continents toward each other, of the Pacific resistance, of the west drift and also finally of the stretching forces of the pole drift, is the rotation of the earth.

The foregoing is only an outline of the most important contents of this book, which impresses the reader with the ingenuity with which the facts of continental drift are presented in connection with the movements of the earth's crust, revealing a group of diverse forces, by means of which the problems of mountain-building seem greatly simplified. Everyone who is interested in this subject should give his consideration to this latest book by Rudolf Staub, who submits the results of his study for further discussion and perfecting. Very instructive illustrations and a map of the principal lines of the Alpine system of the earth, together with a very extended list of publications, increase the value of the book.

GERHARD G. SENFTLEBEN

TULSA, OKLAHOMA
July 29, 1928

"The Petroleum Industry of Roumania," (Extracts and Summary of the Section on Petroleum in "Les Richesses Minières de la Nouville Roumania"). By AUREL P. IANCOULESCO. *The Petroleum Times*, Vol. 20, July 21, 1928, pp. 97-99, and July 28, 1928, pp. 137-39.

Mr. Iancoulesco's treatise covers all branches of the petroleum industry of Roumania, including up-to-date statistical data, and the advance of the industry is shown by the important comparison of the pre-war and post-war periods.

Starting with the many centuries when oil was used only for medicinal purposes and taken from natural seepages and shallow pits, the growth of the petroleum industry is traced as it went from strength to strength and finally in 1912 ranked fourth as a producer of the world. In 1913 its production totalled 1,885,225 tons. The Great War then did its damage to Roumania so far as her world position was concerned, but progress commenced again in 1922 and last year her production was no less than 3,661,000 tons. Exports of petroleum products reached the pre-war maximum in 1913, the total being 1,029,136 tons. This was surpassed in 1926 with a total of 1,492,953, and last year it was 1,912,-982, the principal purchasers (in order) being Italy, Egypt, England, Austria, Germany, and France. Full details covering all countries and the nature of the exports from 1913-27 are given.

Drilling reached its maximum point in 1926 and it was particularly intensive in Moreni, Ochiuri, and Gura Ochitzei. The total depth drilled was 263,000 metres and the cost 11,000 lei per metre.

Details and statistics of production, profits, capital, etc., are given of the most important Roumanian oil companies, the Creditul Minier, the Industria Romana de Petrol, and the Petrolul-Romanese. At the end of 1926 there were 159 oil companies with a total authorized capital of 13,967,525,245 lei, of which 10,712,739,991 lei have been issued.

Roumania had 62 refineries before the war with a total refining capacity of 4,593,474 tons, but only 10 belonging to foreign companies were of any importance. The capacity now is more than 5,000,000 tons of crude a year. Of the Roumanian crude oils, the best known and most valuable are those of Bustenari

and Moreni. The specific gravity of the light spirit is 0.710-0.730 and that of the heavy 0.40-0.784, while that of the kerosene is 0.810-0.830. The development of the cracking processes is discussed from the time the Dubbs process (the first to be used) was adopted at the Colombia refinery. In this way large proportions of residue of little value for export purposes are now being subjected to these processes in increasing proportions. After the war the state was forced to construct pipe lines to relieve the problem of transportation of crude, and in so doing it prevented the formation of trusts such as developed in America. A new society, "Societe des Grandes Conduites," will develop and control the pipe lines from the oil regions to the Black Sea and the Danube.

The period of foreign control before the Great War—when foreign capitalists were masters of petroleum exploitation—and the period of nationalization of petroleum following the war—when real owners of the property entered into complete ownership of their wealth—are discussed in one chapter. Mr. Iancoulesco traces out the formation of important earlier companies, their development and the development by foreign capital to enable petroleum to occupy its important position in European and world markets. Those companies ignored elementary principles of development work such as geology and preliminary testing of other territories so as to maintain and develop production for the future. Therefore, after the war, by means of the national petroleum policy, former German companies were taken over by a Roumanian and Allied group. This policy was consummated by passing the mining law of July 4, 1924, and its application. Roumania had no conception of the importance of her natural deposits because, until 1900, the policy governing conditions for exploiting oil was one of unlimited liberalism to all. Since 1924 all foreign oil companies excepting the Royal Dutch and Standard Groups have given assistance in the application of the mining law which requires the whole of the subsoil to be exploited exclusively by Roumanian companies; the organization of refineries, transport and interior distribution; the imposing of a policy of intensive exploitation; and the establishment of an export policy.

C. G. Bowers[1]

Pittsburgh, Pennsylvania
August 21, 1928

[1]Introduced by K. C. Heald.

RECENT PUBLICATIONS

GENERAL

Analytical Principles of the Production of Oil, Gas, and Water from Wells, by Stanley G. Herold. Stanford University Press, Stanford University, California, 1928. xx + 660 pp., illus. Green cloth. Price, postpaid, $7.50.

"Bibliography of North American Geology, for 1925 and 1926," by John M. Nickles. *U. S. Geological Survey Bulletin 802*. Washington, D. C., 1928. 286 pp. Free.

The Petroleum Register, 1928 Edition. Compiled and published by the Chilton Class Journal Company, Chestnut and 56th Streets, Philadelphia, Pennsylvania. International annual directory, statistical record and equipment

catalogue of the petroleum industry, with maps of the principal producing and prospective territories. 608 pp. Price, $10.00.

"The Problem of Crooked Holes," by F. H. Lahee. *The Oil Weekly*, August 31, 1928, p. 34.

"Standardizing the Open Flow from Natural Gas Wells," by R. R. Brandenthaler, E. L. Rawlins, and T. W. Johnson. *U. S. Bureau of Mines Report of Investigations 2885*, August, 1928. Free.

"Structural Symmetry in North America," by Arthur Keith. *Bulletin Geol. Society of America*, Vol. 39, No. 1, pp. 321-85.

"Isostasy and Mountain Building," by C. O. Swanson. *Journal of Geology*, Vol. 36, No. 5, pp. 411-33.

"Studies of Basin-Range Structure," by Grove Karl Gilbert. *U. S. Geol. SurveyProf. Paper 153*. 92 pp., 57 figs., 40 plates. Free.

ALSACE

"Les recherches récentes de pétrole en Alsace," by Jean Jung. *La Revue Pêtrolifère*, August 25, 1928, pp. 1141-44. Contains geological map.

ENGLAND

"The Oil Well and Later Developments at Hardstoft, Derbyshire," by Arthur Wade. *Journal of Institution of Petroleum Technologists*, Vol. 14, No. 68 (June, 1928), pp. 357-87; 4 figs., 4 photographs.

FLORIDA

"New Species of Operculina and Discocyclina from the Ocala Limestone," by T. Wayland Vaughan. *Florida State Geological Survey*, Herman Gunter, state geologist, Tallahassee, 1928. 11 pp., 2 illus. Price, $0.03, postage.

"New Species of Coskinolina and Dictyoconus from Florida," by M. Wilcox Moberg. *Florida State Geological Survey*. 10 pp., 3 illus. Price, $0.03, postage.

ILLINOIS

"Geology and Mineral Resources of the Herscher Quadrangle," by L. F. Athy. *Illinois State Geological Survey Bulletin 55*. Urbana, Illinois, August, 1928. 120 pp., 38 illus. Price, $0.50.

NEW JERSEY

"Structure Favors Oil and Gas Production in New Jersey," by Alfred C. Hawkins. *The Oil Weekly*, August 17, 1928, pp. 54-56; 3 figs.

SOUTH AMERICA

Manual of South American Oil Companies, 1928 edition. Megargel Publications, Ltd., 1 Wall Street, New York, N. Y. General information on South American oil fields and description of corporations active there. Price, $1.00, postpaid in U. S.

TEXAS

"The Economic Importance of Salt Domes," by Donald C. Barton; "A Neglected Field in Stratigraphy," by J. A. Udden; "Vertebrate Faunal

Horizons in the Texas Permo-Carboniferous Red Beds," by Alfred S. Romer; "The Pennsylvanian and Permian Stratigraphy of the Glass Mountains," by Philip B. King and Robert E. King; "Pseudo-Igneous Rock and Baked Shale from the Burning of Lignite, Freestone County, Texas," by John T. Lonsdale and David J. Crawford; and "Core Drill Tests for Potash in Midland County, Texas," by E. H. Sellards and E. P. Schoch. *Bureau of Economic Geology of the University of Texas, Bulletin 2801.* Austin, Texas. 204 pp., 12 text figs., 6 plates. Price, $1.00.

"Engineering Report of Texhoma-Gose Oil Pool, Archer County, Texas," by Chase E. Sutton, Carol J. Wakenhut, and H. B. Hill. Coöperative report by *U. S. Bureau of Mines* and *North Texas Geological Society*, 1928. North Texas Geological Society, U. B. Hughes, Secretary, City National Bank Building, Wichita Falls, Texas. Price, $0.50.

THE ASSOCIATION LIBRARY

JAPAN

From B. Koto:

"The Intersecting Twin Earthquake of Tango Hinterland in 1927."

TECHNICAL PERIODICALS

The following titles should be added to the exchange list of periodicals bearing on petroleum geology published in the August *Bulletin:*

Geological Review (Denver)
Geologisches Zentralblatt (Leipzig)
Oil Age (Los Angeles)

THE ASSOCIATION ROUND TABLE

NEW RESEARCH COMMITTEE

President R. S. McFarland, in behalf of the executive committee, announces the appointment of a new A. A. P. G. research committee, under the chairmanship of Alex W. McCoy, as follows:

	Term in Years
Alex W. McCoy, *chairman*	1
Charles R. Fettke	1
A. I. Levorsen	1
W. E. Wrather	1
Donald C. Barton	2
W. T. Thom, Jr.	2
F. M. Van Tuyl	2
K. C. Heald	3
F. H. Lahee	3
M. K. Read	3

The terms of the members are to run concurrently with those of the executive committee, expiring, as now established, thirty days after each annual meeting of the Association. Although the terms of the one-year members are necessarily short in order to conform to the ultimate accomplishment of the definite three-year plan, the executive committee favors the re-appointment of short-term members if they are engaged in uncompleted projects at the end of their present terms.

The work of the previous research committee, which was established in March, 1923, with W. E. Wrather, chairman, was described in the chairman's report of progress in the *Bulletin*, Vol. 11, pp. 644-47, and in an article by K. C. Heald in the *Bulletin*, Vol. 12, pp. 939-48.

PACIFIC SECTION FALL MEETING

Bartlett W. Gillespie, secretary-treasurer of the Pacific Section of the Association, announces that the fall meeting of the section will be held at Los Angeles November 1 and 2, preceding the Stanford-U. S. C. football game. The chairman of committees are as follows: General chairman, Vernon L. King, 427 N. Fuller Avenue, Los Angeles; general committee Clarence Osborne; program, H. W. Hoots; hotel, Floyd C. Merritt; finance, E. F. Davis; entertainment, Dana Hogan; transportation, George Suman; registration, Ed. Jussen; ladies' entertainment, Mrs. William Kew.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to J. P. D. Hull, Business Manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

FOR ACTIVE MEMBERSHIP

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E. Russell Lloyd, E. L. Jones, Jr., D. E. Lounsbery
Leo Vernon Horton, Tulsa, Okla.
Frank R. Clark, Wilson B. Emery, L. G. Welsh
Joe Netick, Maracaibo, Venezuela, S. A.
Edward S. Bleecker, Arthur E. Remington, J. A. Tong
John Edward Rea, Amarillo, Tex.
E. Max Bauer, Dewitt T. Ring, H. E. Crum
Guy Joseph Scholl, Wichita Falls, Tex.
F. K. Foster, M. M. Garrett, Archie R. Kautz

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J. B. Burnett, W. A. Oborne, S. W. Lesniak

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William Henry Spice, Jr., Maracaibo, Venezuela, S. A.
J. B. Burnett, W. A. Oborne, S. W. Lesniak

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

THE FIFTH INTERNATIONAL PETROLEUM EXPOSITION is to be held in Tulsa, Oklahoma, October 20-29. Foreign countries are to be represented officially in response to the invitation of the U. S. Government. The exposition management is concentrating on the educational and technical features. The A. A. P. G. again has a booth in the scientific building. Please register there. University, state, and federal engineering and geological exhibits will be worth making a trip to Tulsa to see. Remember the meeting of the petroleum division of the A. I. M. E. in Tulsa preceding the exposition, October 18 and 19. Ask the railroad agent for reduced fare certificate when you buy your ticket.

MR. and MRS. N. I. MOYSE announce the birth of Barbara Lee, on July 18, 1928, at St. John's Hospital, Tulsa, Oklahoma. Mr. Moyse is associated with the Holmes Oil Company at Tulsa.

A. E. HARTMAN, geologist of San Antonio, Texas, is associated with C. H. Bailey, with offices at 909 Milam Building, and is engaged in lease, royalty, and drilling propositions.

LAURA L. WEINZIERL, formerly micro-paleontologist with the Marland Oil Company, has had an office during the past year with ALEXANDER DUESSEN at 1606 Post-Dispatch Building, Houston, Texas.

CLYDE M. BENNETT has resigned as president of the Trinidad Oilfields, Inc., and as managing director of the Trinidad Oilfields Operating Company, and has joined the Vacuum Oil Company as executive head of the crude oil department succeeding W. C. Brower, retired. Mr. Bennett will make his headquarters at Houston, Texas.

T. O. BOSWORTH, petroleum mining geologist and engineer, Spratton, Northampton, England, has gone to Ecuador and Colombia. His temporary address is Santa Elena, Ecuador.

WALTER E. HOPPER, recently with the Bethany Oil and Gas Company, is now with the recently organized Arkansas Natural Gas Corporation, with office at 813 Ardis Building, Shreveport, Louisiana. The new corporation resulted from a merger, April 1, 1928, of the Arkansas Natural Gas Company, the Natural Gas and Fuel Corporation, and the Industrial Gas Company, and the purchase of the Arkansas Fuel Oil Company, the Bethany Oil and Gas Company, and the Public Utilities Corporation of Arkansas. The corporation is

owned by Henry L. Doherty and Company of New York. E. A. STILLER has charge of the geological work. WORTH W. McDONALD is in the land department.

R. B. GRIGSBY, of the geological staff of the Dixie Oil Company, Inc., has moved from Wichita Falls, Texas, to Owensboro, Kentucky.

The University of Texas at Austin, Texas, and the University of Tulsa at Tulsa, Oklahoma, are offering, this fall for the first time, courses in petroleum engineering. T. U. TAYLOR is dean of engineering at Austin, and R. C. BECKSTROM is dean of petroleum engineering at Tulsa.

WILLIAM TAYLOR THOM, JR., has returned to his duties as associate professor of geology at Princeton University after spending the summer in southern Oklahoma for the U. S. Geological Survey. The federal and state surveys are coöperating in preparing a report on the coal and related stratigraphy and structure in Haskell and northern LeFlore counties, Oklahoma.

The Netherlands Indies Pacific Research Committee has announced the FOURTH PACIFIC SCIENCE CONGRESS to be held at Batavia and Bandoeng, Java, May 16-25, 1929. The A. A. P. G. is invited to participate. The program provides for papers in the three divisions of physical, biological, and agricultural sciences. Subjects to be included cover results of gravity determinations upon the Pacific Ocean, geophysical means of prospecting, earthquakes, oceanography, meteorology, and paleontology. The congress is supported by the Netherlands Indies government. The official language is English. Abstracts of papers must be in the hands of H. J. Lam, first general secretary of the Fourth Pacific Science Congress, Botanical Gardens, Buitenzorg, Java, by January 1, 1929. Further information may be obtained from Herbert E. Gregory, chairman, committee on Pacific investigations, National Research Council, B and 21st Streets, Washington, D. C.

R. G. REESE has moved from Long Beach to 631 South Greenleaf Avenue, Whittier, California.

RUAL B. SWIGER, recently at Coleman, is now at 905 San Pedro Street, San Antonio, Texas.

CHARLES D. VERTREES, of the Marland Production Company, has been transferred from San Angelo to the San Antonio district. His address is 450 East French Place, San Antonio, Texas.

The A. I. M. E. meeting at Boston, Massachusetts, August 29-31, 1928, was devoted largely to geophysical methods of prospecting. *Mining and Metallurgy* for September contains abstracts and excerpts of the papers, and one paper in full: "Discovery of Salt Domes in Alsace by Electrical Exploration," by G. Carrette and Sherwin W. Kelly, illustrated by three figures.

MARION H. FUNK has resigned his position as district geologist for The Pure Oil Company at El Dorado, Arkansas, to become chief geologist for

Belchic and Laskey of Shreveport, Louisiana. Mr. Funk is temporarily stationed at Ada, Oklahoma, where his firm is engaged in producing natural gas.

CHARLES E. DECKER, professor of paleontology at the University of Oklahoma, spent two weeks in August at the U. S. National Museum, collaborating with E. O. ULRICH on a standard geologic section for the early Paleozoic of Oklahoma.

GEORGE R. ELLIOTT, of Long Beach, has an article on "History and Geology of Latest California Field (Hawthorne)" in the *Oil Weekly* of September 7, 1928.

GLEN M. RUBY has finished his ground work preparatory to getting a pilot's license, which will enable him to fly his own plane over the Hudson Bay Company lands, and other areas in Canada where he is doing pioneer work.

RANSOM E. SOMERS and KENNETH C. HEALD, of the Gulf Companies, are lecturers, and R. E. SHERRILL, of Cornell University, is an instructor at the University of Pittsburgh.

PRENTISS D. MOORE is giving his entire attention to the development program of the Imperial Oil Company in the Turner Valley field, Alberta, Canada.

JOSEPH H. SINCLAIR has been chosen by the New Encyclopedia Britannica to re-write the section devoted to Ecuador and the Galapagos Islands.

THEODORE A. LINK, who is in charge of the Imperial Oil Company's office at Calgary, spent the summer checking structures in the foot-hill belt north of the Turner Valley field.

DIRECTORY OF GEOLOGICAL SOCIETIES

FOR THE INFORMATION OF GEOLOGISTS VISITING LOCAL GROUPS. FOR SPACE, APPLY TO THE BUSINESS MANAGER, BOX 1852, TULSA, OKLAHOMA

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